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THESIS

ANALYSIS OF THE PREVENTIVE/CORRECTIVE MAINTENANCE RATIO FOR DDG CLASS SHIPS

by

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13. ABSTRACT (maximum 200 words)

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The research examined the 1:1 (electrical) and 2:1 (mechanical) ratios used to accurately forecast CM. The study analyzes effects to the SMD when actual Open Architectural Retrieval System (OARS) CM data is used. This study used one Engineering and one Combat Systems work center as a baseline. CM OARS data for the work centers was provided by NAVSEA and PM data was provided by NAVMAC.

Findings indicate that across all DDG [flights], the PM:CM ratio understates the amount of CM performed. The resulting ratio for electrical maintenance was 1:10.9 and for mechanical maintenance 1:1.64. When CM from OARS was used to determine SMD requirements as outlined in OPNAVINST 1000.16K, it resulted in increased functional work on all flights of DDGs.

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ANAYLYSIS OF THE PREVENTIVE/CORRECTIVE MAINTENANCE RATIO FOR DDG CLASS SHIPS

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LIST OF ACRONYMS AND ABBREVIATIONS

CBM	Conditioned Based Maintenance
CM	Corrective Maintenance
CNA	Center for Naval Analysis
CNO	Chief of Naval Operations
CNP	Chief of Naval Personnel
DDG	Guided Missile Destroyer
DON	Department of the Navy
FMD	Fleet Manpower Document
FM	Facility Maintenance
HSI	Human Systems Integration
IG	Inspector General
INSURV	Inspection and Survey
ISMAT	Integrated Simulation Manning Analysis Tool
MIP	Maintenance Index Pages
MR/PA	Make Ready/Put Away
MRC	Maintenance Requirement Card
NAVMAC	Navy Manpower Analysis Center
NAVSEA	Naval Sea Systems Command
NEC	Navy Enlisted Classification Code
NMRS	Navy Manpower Requirements System
NMSO	Navy Maintenance Support Office

OARS	Open Architecture Retrieval System
OMMS	Organizational Maintenance Management System
OUS	Own Unit Support
PA	Productivity Allowance
PM	Preventive Maintenance
PMS	Preventive Maintenance System
POE	Projected Operating Environment
OPNAV	Office of the Chief of Naval Operations
ROC	Required Operational Capabilities
SMD	Ship Manpower Document
SMDDP	Ship/Fleet Manpower Document Development Procedures Manual
SMRD	Shore Manpower Requirements Determination
SQMD	Squadron Manpower Document
SURFMER	Surface Ship Maintenance Effectiveness Review
UIC	Unit Identification Code
USN	United States Navy
3-M	Maintenance and Material Management System
3-MC	Maintenance and Material Management System Coordinator

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Luz V. Ortiz

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-Martin Fajardo

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I. INTRODUCTION

A. AREA OF RESEARCH

The goal of this research was to evaluate the corrective maintenance in Open Architecture Retrieval System (OARS) for U.S. Navy Guided Missile Destroyer (DDG) class ships. The analysis examines the accuracy of the corrective/preventive maintenance ratio currently used to determine Navy Manpower requirements. Research included conducting a detailed analysis of OARS maintenance data of the DDG-51 class, a review of current ship board maintenance instructions, and analysis of the current Preventive Maintenance: Corrective Maintenance (PM:CM) ratio.

B. RESEARCH QUESTIONS

Primary Question

1. Does the current corrective maintenance in the SMD represent actual work as reported in the NAVSEA Open Architectural Retrieval System (OARS) database?

Secondary Question

1. How does maintenance workload affect manpower requirements?

C. DISCUSSION

Navy Manpower Analysis Center (NAVMAC) determines wartime requirements based on a notional 60-day at-sea, wartime scenario as defined by the Required Operational Capability/Projected Operational Environment (ROC/POE). During this time, all PM:CM workload is tracked separately from PM:CM workload completed in and around CONUS. During wartime, only essential CM that will maintain equipment in optimal wartime readiness status is be performed. One output factor is that CM performed during deployments may be substantially less than when the ship is in port.

Since the inception of the Surface Ship Maintenance Effectiveness Review (SURFMER), PM has decreased on Navy ships by 40 percent (Olinger, 2002, p. 2). The reduction in PM has caused a corresponding reduction in CM. In maintenance intensive departments such as Deck and Engineering, this can equate to substantial manpower reductions. The PM:CM ratio is one of the variables used in formulating manning requirements. As with all systems relying on human data recording routines, insufficient and/or inaccurate input degrades results and performance.

D. SCOPE

The scope and direction of this study included the following: a review of OARS corrective maintenance for 51 DDG type ships for a deployment lasting more than 60 days between 2008 and 2010 and a PM:CM ratio was generated using NAVMAC's established ratio formula and guidance from OPNAVINST 1000.16K.

E. ORGANIZATION OF STUDY

Chapter I: The introduction identifies the purpose of the research as stated in the primary and secondary research questions.

Chapter II: Contains a literature review of paper and electronic publications pertaining to the research.

Chapter III: Methodology

Chapter IV: Manpower Requirements Process

Chapter V: Summary, conclusion, and recommendations

II. LITERATURE REVIEW

A. INTRODUCTION TO LITERATURE REVIEW

This chapter provides a general overview of corrective and preventive maintenance (PM:CM) literature related to the establishment of manpower requirements aboard U.S. Navy ships. There has not been a study on PM:CM since a Center for Naval Analyses (CNA) study 24 years ago showed that the PM:CM ratio used by the Navy was understated (Lurie, 1987). Technical reports and periodicals on Human Systems Integration (HSI), lean manning, and Navy mishap data provide underlying information for understanding the relationship between maintenance manpower and manning levels on Navy ships.

The review is divided into four sections; Section B provides a military regulatory framework based on Department of the Navy (DON) policy and maintenance. Section C reviews background materials from the Navy's manpower and personnel organization, the Navy Manpower Analysis Center (NAVMAC) in Millington, TN. Section D introduces a third set of underlying material including findings from two NPS theses about U.S. Navy shipboard operational and functional manning. Section E concludes the review by linking the topic area with some current Navy manpower and manning challenges including functional maintenance, operational and Lean manning (Ewing, 2009).

B. NAVY GUIDANCE

OPNAV Instruction 4700.7K, Maintenance Policy for U.S. Navy Ships, includes 39 references and seven enclosures clarifying the maintenance policy. It specifically instructs commanders to utilize the Maintenance and Material Management System (3-M) system as the primary management tool for maintenance on all non-nuclear Navy ships (Department of the Navy, 2007, p. 5). Although the instruction is relatively lengthy

and detailed in explaining maintenance procedures, the Open Architectural Retrieval System (OARS) is not mentioned as a planning, documenting, or reporting tool in any part of the instruction text, or in the enclosures.

OPNAVINST 4790.4E, Ship's Maintenance and Material Management (3-M) System Policy establishes policy and assigns responsibility for 3-M using the previously discussed OPNAVINST 4700.7K.

Section 5 of OPNAVINST 4790.4E, clarifies that accurate documentation of maintenance is required for controlling and evaluating manpower and material resources used to support maintenance. The accuracy of documenting maintenance is a precursor to monitoring a ship(s) operating costs.

OPNAVINST 4790.16, Condition Based Maintenance (CBM) Policy, applies to all U.S. Navy ships and aircraft, except for those operated by civilians. The CBM strategy is to "perform maintenance only when there is objective evidence of need, while ensuring safety, equipment reliability, and reduction of total ownership cost. The goal is to optimize readiness while reducing maintenance and manning requirements" (OPNAV INST 4790.16, 1998, p. 1). Section 5, part j, assigns responsibility to the Deputy Chief of Naval Operations (Manpower and Personnel) to coordinate the implementation of manpower reduction initiatives resulting from the implementation of CBM procedures. Throughout the instruction, two objectives are made clear; reduce operating costs and manning using CBM.

This CBM instruction captures a common business production conclusion that reduces maintenance requirements and translates them into reduced operating costs. The successful use of proven new technology can maximize workload and potentially reduce the numbers of personnel needed, e.g., ATM machines and fewer bank tellers (Ewing, 2009) found that Navy ships following the instruction tended toward reduced maintenance hours. Yet alongside that positive result, Ewing found negative climate/cultural behaviors that may or may not be related issues surrounding corrective and preventive maintenance (PM:CM). He perceived a decrease in sailor morale, increase work hours, indication of work-hour misrepresentation, and an increased risk for

accidents and injury (Ewing, 2009). Evolution frequency tables project aspects of tasks performed at sea during a sixty-day at-sea period. These tables assist commanders in preparing manpower documents for underway periods. One observation limitation is that the frequency tables do not provide information on the rank or number of personnel required to conduct an evolution. Ships are listed by ship class number, and columns show the brief title of a particular evolution. Under each evolution are the numbers of personnel needed to accomplish the task. This table is the primary source for computing corrective and preventive maintenance ratios needed to perform all routine maintenance in normal, condition 3 underway steaming for 60 days (Cox, 2002, p. 1). The cruiser and destroyer Evolution Frequency Table is shown in Table 1.

EVOLUTION FREQUENCY TABLE										
	NAV	**REPLENISHMENT**					**OP DETAIL**			
	SEA AND ANCHOR	REFUEL	REPROVISIONING	RARM	VERTREP	RIG AND UNRIG	HELO OPS	LOW VIS	STRIKE DOWN	LIFE GUARD/PLANE GUARD
CG 47	3	20	4	2	6	32	*	4	6	10
DD 963	3	20	4	2	6	32	*	4	6	10
DDG-51 FLT I & II	3	20	4	2	6	32	*	4	6	10
FFG 7	3	20	4	2	6	32	*	4	6	5

Table 1. Evolution Frequency Table (From Cox, 2002, p. 2)

C. NAVAL MANPOWER AND ANALYSIS CENTER DOCUMENTATION

The following includes memorandums, presentations, and correspondence relating to maintenance requirements for Navy ships.

OPNAV Instruction 1000.16K, Navy Total Force Manpower Policies Procedures, provides the policies and procedures required to develop, review, approve, and implement an update Total Force manpower requirements and authorizations for all naval activities (Unites Sates Navy, 2007, p. 2-1). Section 3 specifically addresses fleet manpower requirements determination.

The Ship/Fleet Manpower Document Development Procedures Manual (SMDDP) encompasses three manpower development systems; the Ship or Fleet Manpower Document (SMD/FMD) Program, the Squadron Manpower Document (SQMD) Program, and the Shore Manpower Requirements Determination (SMRD) program. Basic manpower requirements are “zero-based”. Using zero-based planning, requirements are submitted without regard for funds, available number of personnel, or available shipboard berthing. Once manpower levels are projected, commanders must justify their requirements by providing approved operational requirements using the Required Operational Capabilities (ROC) and Projected Operational Environment (POE) (United States Navy, 2007, p. 2–1).

Section 404, the Navy Standard Workweek, is a key element in determining accurate manpower requirement levels. The Navy standard workweek applies to all ships, afloat staffs, mobilization units, and Number Fleet Commanders unless specifically precluded. Using the Navy standard workweek analysis a sailor is available for 168 hours of which, 70 are allocated for productive work. Of those 70 hours, 56 are dedicated to primary watch-standing leaving 14 hours to perform maintenance related functions (Department of the Navy, 2007, p. C1–C9).

Training material created by analyst at NAVMAC for in-house training was used to explain the use of documented maintenance hours as an input factor in the development of manpower requirements. There are five basic types of maintenance performed on ships at sea under Condition III:

- Daily checks
- Weekly checks
- Monthly checks
- Quarterly checks
- “R” checks- unscheduled maintenance

The data is converted to average “weekly” hours spent on maintenance. The data is collected and separated by rate, Navy Enlisted Classification Code (NEC), and division for each ship and type. Make ready/put away (MR/PA) is accounted for with a factor of 15 percent added to the baseline allotted for each job. This allowance is applied only preventive maintenance only. MR/PA accounts for preparation, tool gathering, necessary cleanup, tag outs, and other steps that do not include directly performing the maintenance function.

Corrective maintenance ratios describe the relationship between corrective maintenance completed in relation to the preventive maintenance performed. The ratios are applied based on the type of equipment being maintained. A 2:1 ratio of PM:CM is applied to mechanical equipment, and a 1:1 PM:CM ratio is applied to electrical equipment.

Productivity Allowances (PA) account for delays due to fatigue, environmental effects, personal needs, or other unavoidable interruptions that increase the baseline time for the job. The percentage increase for PA is between 2–8 percent and is only applied to corrective, own unit support, and facilities maintenance actions. PA levels were previously set a 20 percent across the board, but were reduced in 2002, by OPNAV N12 during his lean manning initiative. The reduction of 12–18 percent in PA allowances along with other changes resulted in a decrease in required manpower (Stengel, 2008, p. 8).

Productivity Allowance (Percent	Typical Jobs
2 percent	Work is conducted in a temperature-controlled environment. It is normally administrative in nature with minimal maintenance and the level of physical effort is light. Any watches would normally be conducted under environmentally controlled conditions. However, it would not be unexpected for an individual to b exposed to the weather for short periods of time. Noise levels are relatively low.
4 percent	Work is mostly conducted in a temperature-controlled environment with light to moderate maintenance. May be slightly dirty or greasy where the level of physical effort is moderate. However, personnel may minimal/nominal exposure to weather and/or be physically stressful. Situational awareness is necessary, but not distracting.
6 percent	Work is conducted in a light industrial environment or partially exposed to the weather and may encounter disagreeable odors. The level of physical effort is significant. Personnel may be subjected to noise and/or heat stress monitoring. Personal injury is possible but not immediately expected. Situational awareness is required, but does not require continuous safety supervision.
8 percent	Work is conducted in a heavy industrial environment or personnel are continuously exposed to the weather and/or disagreeable odors and fumes, etc. The level of effort is heavy and personnel may be subjected to continuous noise and/or heat stress monitoring. Personal injury can be expected under hazardous conditions and a heightened situational awareness is required.

Table 2. Productivity Allowance Table (From McGovern, Ship/Fleet Manpower)

Commander R. E. Loken developed an instructional memorandum to introduce the concept of corrective maintenance to personnel unfamiliar with it. Corrective maintenance is directly related to preventive maintenance that is based on data in each ship's 3-M system. As described in the previous document there is a ratio between preventive and corrective maintenance. This ratio was developed in 1985, and is used when corrective maintenance data is not available for use (Loken, 2001, p.1).

Documentation of corrective maintenance is required in the Organizational Maintenance Management System (OMMS). NAVMAC has access to CM data using the OARS. Although OARS collects CM data that can be sorted by ship class, unit identification code (UIC), hull number, work center, rate, and NEC it does not have the ability to identify CM that was performed underway.

Loken's memo brings up the main issue of this research; CM levels do not seem to be accurately documented when a ship is underway. Whether mission needs take precedence or an increase in workload lessen the importance of the Maintenance Material Manager Coordinator (3MC) inputting all CM data during deployments, there seems to be a disparity in the reporting of CM data when ships are underway.

In e-mail correspondence shared by NAVMAC, Machinist Mate Senior Chief, (SW) Mark Opasinksi discusses the problems with the current method of reporting and gathering preventive maintenance and corrective maintenance data. The lack of a standardized reporting method and an OMMS system that is not user friendly has 3-MCs choosing not to report maintenance performed. Some commands believe "more data = more people", so erroneous data is being recorded resulting in inaccurate figures being represented in OARS (Opasinski, 2008).

Opasinski offers possible solutions like tailored CM multiples based on ship class, and using PMS as the only reporting system; however, insists that any changes must be Navy wide and have full support from all levels of management.

D. PREVIOUS STUDIES

Previous analysis is limited to a Center for Naval Analyses (CNA) study performed by Philip Lurie in 1987 (Estimating Maintenance Workloads with PM:CM Ratios, CRM 87-39). The Lurie study evaluated maintenance on 14 electrical and 15 mechanical systems over a three-year period for the Navy Maintenance Support Office (NMSO). His data showed the ratio for electrical systems was 1:4.3, and for mechanical systems it was 1:3.12, both higher than the ratios established by the Navy (Lurie, 1987, p. 5–6).

Other work of interest on this area was a thesis by Lieutenant Lazaretti that researches Human Systems Integration (HSI), a "process designed to reduce life-cycle costs and improve system performance by considering human-related domains" (Lazaretti, 2008, p. 1). Although research related to preventive and corrective

maintenance ships on Navy has not been performed in over 25 years Lazaretti's thesis used maintenance, manpower and mishaps, and system performance data in support of his conclusions.

While no causal relationship was found between manpower and mishaps in his particular study, Lazzaretti attributed this to a lack of useable manpower data. Current data is not able to distinguish the difference in work performed underway with maximum manning levels and work performed in port with lower manning levels. The difference in weekly work hours also decreases between at sea and in port time periods. The lack of ability to distinguish between manning and functional workload causes the average weekly work hours per sailor to be inaccurately derived for the appropriate manning levels (Lazzaretti, 2008, p. 48).

In a separate study, Manning and Automation Model for Naval Ship Analysis and Automation, Lieutenant Tyson Scofield specifies that human resources are the largest lifecycle expense in maintaining a ship. He argues that if more attention were paid the development and design of new ships it could directly lead to a reduction in long-term manning costs. Scofield introduces the Integrated Simulation Manning Analysis Tool (ISMAT) that uses the ship type, systems, and maintenance strategy and automation level of the ship to determine accurate manning levels. Scofield developed this program and tested it on an Air Superiority Cruiser (CG-X) as part of the research (Scofield, 2006).

In his conclusion, Scofield noticed that maintenance had an insignificant effect on ship manning levels. The most important determinants of manning were automation level of the ship and the length of the ship. Scofield noted the effects of maintenance on manning as "surprising" and suggested that the accuracy of maintenance data should be researched for accuracy. He proposed that studies be done to assess the actual time spent on maintenance tasks relative to other tasks. It is important to note that this is the same conclusion reached by the staff at NAVMAC.

E. PERIODICALS

When OPNAV N12 reduced PM:CM ratios in 2002 it led to a decrease in the manpower requirement across all Navy ships. The decrease of more than 60,000 sailors

since has caused some sailors to voice concerns about unit morale, safety, mishaps and retention. Although the articles do not mention maintenance as an agitator, the reduction in maintenance ratios caused a reduction in manpower requirements. These articles show the importance of being able to accurately derive manning levels for ships.

The Navy Inspector General (IG) has investigated recent mishaps onboard Navy ships and concluded that,

> Manning issues abounded throughout the region and clearly represented the greatest concern with regard to commanders' ability to safely and effectively accomplish their missions…Numerous manpower reduction initiatives, combined with manpower 'taxes' on commands to accomplish external missions, severely test many commands' ability to function. (Ewing, 2009)

In 2002, the Navy changed the standard workweek from 67 hours to 70 hours of productive work. According to Commander Bill Hatch, Ret., the increase of three hours over 350,000 sailors meant that manpower analyst formulas would reflect requirements that optimally called for fewer personnel. Some ships (destroyers/cruisers) lost about 40 to 50 sailors each. The ships technology did not change, and they have prematurely aged as shown in recent failures of INSURV (Inspection and Survey) inspections. Maintenance requirements have remained the same, but the number of sailors available to address the maintenance is now lower (Ewing, 2009).

The introduction of condition based maintenance has also been used to reduce manning requirements. Condition based maintenance requires maintenance to only be performed when needed. The requirement for preventive maintenance is removed that reduces the number of hours spend on maintenance. That change is also reflected in manning requirements that are produced by NAVMAC analysts.

Recently Vice Admiral Harvey has acknowledged that "lean manning" has not worked the way it was intended. Currently the Navy is assessing ship crew levels and adding billets where required to fix the problems encountered (Ewing, 2009).

In response to a blog that begins with the quote, "fewer resources mean that there are things we will do less, but not less well." Admiral Harvey responds with "…we are

not free to do anything less well” (Harvey, 2010). Vice Admiral Harvey implores his commanding officers to be honest while assessing the capabilities of their crew, and when indicating what missions they will be able to complete.

He makes it clear that if a ship does not have the resources to train, equip, and man for all missions, then the commanding officer is in a position to prioritize requirements or not do them all well. He asks his commanders to “commit” truth and follow the facts. It is understandable from his words that he knows that manning is not optimal on all ships currently and some missions will not be able to be done. His point is just that commanding officers must relay the truth up the chain of command for changes to take place.

F. SUMMARY

Fleet mission and material readiness relies on proper manpower, manning, and training. Having the wrong quantity or quality of sailors on board can have a negative impact on mission and readiness. It is paramount that Navy manpower requirements are calculated using accurate metrics.

Ships are built around designed capabilities and mission in mind. Those capabilities will be degraded without adequate supporting manpower. Today’s Force Protection postures rely on sailors that are just as busy in port as underway. Ships have external manpower requirements to supplement Naval Station security, gate guards, and own ship security while in port. Reduced manning initiatives may lead to a multitude of unintended consequences including longer workdays, less security, and reduced retention.

The inceptions of optimal manning, change in training method, and increased in-port workload, have made it increasingly difficult for ship crews to keep up with shipboard maintenance. Reviewing PM:CM data and re-assessing the ratio to determine if the current manning levels are adequate is a necessary step to ensure fleet readiness.

III. METHODOLOGY

A. METHODOLOGY OVERVIEW

The methodology used in this research consisted of the following steps:

1. A literature review was conducted on applicable books, defense articles, CD-ROM systems, theses, Internet, and other library information resources on the topic.

2. Conducted a thorough review of PM:CM maintenance requirements and standards.

3. Conducted a thorough review of ship Manpower requirements and OARS reporting system.

4. Conducted an extensive data analysis on DDG corrective maintenance data provided by NAVSEA pertaining to all corrective maintenance jobs entered into the OARS system between June 2008 and August 2010. There were a total of 54,683 jobs entered reviewed. The data was organized by ship class, hull, and work center.

5. Using deployment information from the Naval History and Heritage Command and Navsource, we selected a deployment period of sixty days or longer for each ship. Corrective maintenance data from these dates was used to generate the PM:CM ratio for each ship.

6. Using the analyzed data, a graphic representation was produced that compared the PM:CM ratio derived from the CM data and compared it to the standard PM:CM ratio determined by NAVMAC.

7. Provide recommendations based on this analysis for future review/study if an improved approach to the documenting of corrective maintenance would result in a better defined PM:CM ratio that can be applied to all Navy ships.

B. DATA DESCRIPTION

The following table provides a description of the variables provided in the data set:

VARIABLE	DESCRIPTION
SHIP CLASS	Enter Ship Class. Named after the lead ship; that is, the first ship of that class to be approved by Congress—almost (but not quite) without exception the ship of the class with the lowest hull number.
UIC	Enter the UIC of the activity initiating the maintenance action
SHIP TYPE HULL	The ship type and hull number of the activity originating the maintenance action. Not required by activities other than ships.
WORK CENTER	Enter the work center code of the work center initiating the maintenance action. For ships, a four position work center code will be entered.
JOB SEQUENCE NUMBER	Enter the character job sequence number assigned by the work center supervisor. This is an entry assigned sequentially from the SFWL/JSN log.
RATE	Enter the rate of the first contact/maintenance person.
SHIP FORCE MAN HOURS	The total man hours (to the nearest whole hour) that ship's force used doing the maintenance after submitting the deferral. It includes witnessing of tests, and those manhours expended in reinstallation, test, documentation, etc. Documentation time cannot exceed "1" hour.
ACTIVE MAINTENANCE TIME	Total clock hours (to the nearest whole hour) during which ship's force maintenance was actually performed. This should include time for troubleshooting, but not delays.
TYPE AVAILABILITY CODE	Type of availability recommended for performance of a deferral. Code Description 1. Depot (shipyard or ship repair facility) 2. Intermediate Maintenance Activity (tender, repair ship, etc.) 3 . TYCOM Support Unit (floating dry dock, etc., or technical assistance from NAVUNDERSEAWARCEN, DETACHMENT FTSCLANT, FTSCPAC or contractor representative) 4. Ship's Force 0. Not Applicable U. Mission Degrading Used by INSURV, field identifies certain deficiencies that are considered as preventing the ship from carrying out some part of its mission.
ACTION TAKEN CODE/MAINTENANCE ACTION	A code to describe the maintenance action taken. Select the code that best describes the action taken to complete the maintenance. When recording these codes, start in the left justified position of the field. The first character is to be chosen from the list below; the second character is free-form and is to be recorded as specified by the TYCOM. MAINTENANCE ACTION: For maintenance action reporting, the following action codes can be used: Code Description 1. Maintenance Action Completed; Parts Drawn from Supply 2. Maintenance Action Completed; Required Parts Not Drawn from Supply (local manufacture, pre-expended bins, etc.) 3. Maintenance Action Completed; No Parts Required 4. Canceled (When this code is used, the deferral will be removed from the CSMP. This code is not to be used with INSURV, safety, or priority 1 or 2

VARIABLE	DESCRIPTION
	deferrals screened for accomplishment by the TYCOM or IUC.) 7. Maintenance Action Completed; 2-M (Miniature/Micro miniature Electronic Modules) Capability Utilized 8. Periodic Time Meter/Cycle Counter reporting. (This code is not applicable to the "FINAL ACTION" code reported by the repair activity.) 9. Maintenance Action Completed; 3M Fiber Optic Repair
EQUIPMENT NOMENCLATURE	Enter the equipment nomenclature/description that maintenance is being reported. The equipment nomenclature/description should be the same as that identified by the Equipment Identification Code (EIC) and is limited to 16 positions.
APL	Allowance Parts List/Allowance Equipment List. Enter the APL/AEL of the equipment being reported. These numbers are found in the COSAL or SCLSIS Index report. An example of an APL would be “882170236” and an AEL would be “2-260034096.”
CSMP NARRATIVE SUMMARY	Enter a condensed description of the problem. The work center supervisor is to ensure the summary succinctly captures the meaning of the REMARKS/DESCRIPTION narrative. The CSMP summary conveys to management the significance of the JCN (maintenance action). The CSMP summary is displayed on management reports, as opposed to the entire narrative of the REMARKS block.
PROBLEM DESCRIPTION	Provide information that describes the problem and what caused the failure (if known)
ACTUAL SOLUTION	Enter steps and actions that must be taken to correct the problem.
DATE OPENING	The Julian date the document is prepared.
DATE CLOSING	The Julian date the work request is completed and signed off by the requesting ship.

Table 3. OARS CM Database Headings with Descriptions (From NAVSEA, 2003)

C. DATA ANALYSIS

Data was scrubbed and analyzed under three different scenarios in order to present the best and worst possible PM:CM ratios.

Scenario 1: A deployment of 60 or more days was selected for each ship. For the deployment period selected, all jobs that were entered as completed by a civilian

contractor were removed. All remaining jobs that were either started or completed during the specified deployment dates were used in the derivation of the PM:CM ratio.

Scenario 2: A deployment of 60 or more days was selected for each ship. For the deployment period selected, all jobs that were entered as completed by a civilian contractor were removed. All jobs that were considered facilities maintenance were not included in the established PM:CM ratio calculation. All remaining jobs that were either started or completed during the specified deployment dates were used in the derivation of the PM:CM ratio.

Scenario 3: A deployment of 60 or more days was selected for each ship. For the deployment period selected, all jobs that were entered as completed by a civilian contractor were removed. All jobs that were considered facilities maintenance were not included in the established PM:CM ratio calculation. Of the remaining jobs, only those that were started and completed during the deployment were started and completed during the specified deployment dates were used in the derivation of the PM:CM ratio.

IV. MANPOWER REQUIREMENTS PROCESS

A. SURFACE SHIPS MANPOWER REQUIREMENTS OVERVIEW

Manpower requirements represent measured workload in support of the number of personnel required to perform the Navy's mission. OPNAVINST 1000.16K states that "manpower requirements shall reflect the minimum quantity, calculated using the approved Navy Standard Work Weeks, and quality of manpower required for peacetime and wartime to effectively and efficiently accomplish the activity's mission" (p. 2-2). A requirement equates to a space that is assigned specific qualifications that are required to accomplish the assigned task, function, or duty. There are four types of manpower requirements: Fleet, Shore, Individual Accounts, and Outside Navy Requirements. For purposes of this study, we will discuss how Fleet Manpower Requirements are determined.

Fleet Manpower Requirements are determined by NAVMAC and represent work requirements on ships, squadrons, and other deployable units. Fleet Manpower Requirements is a standards-based system governed by required operational capabilities and projected operational environments (ROC/POE) and approved by the Chief of Naval Operations (CNO). A ROC/POE is therefore a foundation document that manpower requirements are determined from. Inaccurate reporting of operational capabilities and mission tasking may result in a loss of money or manning essential to accomplishing the platform mission (McGovern, 2003, p. 2–1). OPNAVINST 1000.16K states, "Total Force requirements shall reflect the appropriate mix of military, civil service and private sector manpower necessary to accomplish DOD missions consistent with applicable laws, policies, and regulations (p. 2-2).

B. ROC/POE

1. Required Operational Capabilities

The DDG-51 ROC is established by OPNAVINST 3501.311A. Required operational capabilities are reported as readiness conditions. A readiness conditions is "a statement that describes an action that must be performed by a ship in support of its assigned mission. These capability statements provide the necessary detail and criteria for translating tasking to the manpower required to perform the various operational, maintenance, and support tasks essential to effective performance of the mission for all conditions of readiness" '(McGovern, 2005, p. II-2). Readiness applies to watch standing and/or evolutions and other work applies to non-watch standing activities such as performing maintenance. The following summarizes the readiness conditions:

- Condition I: (Battle Readiness). All personnel are continuously alert. All possible operational systems are manned and operating. No maintenance is expected except that routinely associated with watch standing and urgent repairs. Maximum expected crew endurance at Condition I is 24 continuous hours.
- Condition II: (Limited Action). Accomplishment of urgent underway PM and support functions is expected. A minimum of four to six hours of rest is provided per man per day. Subject to these conditions, required operational systems are continuously manned and operating. Maximum expected crew endurance at Condition II is ten continuous days.
- Condition III: Wartime Cruising Readiness. Operational systems are manned and operating as necessary, to conform with prescribed ROCs. Accomplishment of all normal underway maintenance, support, and administrative functions is expected. Opportunity for eight hours of rest provided per man per day. Maximum expected crew endurance at Condition III is 60 continuous days.
- Condition IV: Peacetime Cruising Readiness. Operational systems are normally manned only to the extent necessary for effective ship control, propulsion, and security.
- Condition V: In port Readiness. Systems and watch stations are manned to the extent necessary for effective operations as dictated by the existing situation. Watch stations are assigned as required to provide adequate security. Personnel on board are at all times adequate to meet anticipated in port emergencies and perform in port functions as prescribed by unit

> ROCs. Accomplishment of all required maintenance, support, and administrative functions is expected. Maximum advantage is taken of training opportunities. Subject to the foregoing requirements, the crew will be provided maximum opportunity for rest, leave, and liberty. (McGovern, 2005, p. II-1)

2. Projected Operational Environment

The DDG-51 POE is established by OPNAVINST 3501.311A. The POE defines the circumstances and environments the DDG-51 is anticipated to work under while maintaining Readiness Condition I thru V. Per OPNAVINST 3501.311A (enclosure 1), "the DDG-51 Class shall be capable of performing all assigned primary mission areas simultaneously while maintaining Readiness Condition I, II, III (wartime/forward deployment cruising readiness), IV (peacetime training underway operations) or V (in port training and maintenance)"

C. WORKLOAD DETERMINATION

Determining the correct functional workload is the beginning of the manpower determination process. Workload determination consists of operational manning (watch stations), planned and corrective maintenance, and facility maintenance. Administrative support, command, supply, and medical requirements are also accounted for in this process. Additional tasks referred to as evolutions such as replenishment at-sea is also considered. Actual work is measured through the use of industrial engineering techniques, frequent on-site observations conducted by trained NAVMAC analysts, and the use of supplemental data from Navy management information systems such as Maintenance and Material Management (3M) System.

D. NAVY STANDARD WORKWEEK

The Navy Standard Workweek is a key element used in determining manpower requirements. The Navy Standard Workweek, shown in Figure 1, establishes a guideline for sustaining personnel during wartime or peacetime conditions. For purposes of this study, we will focus on the Navy Standard Workweek Afloat. Once the workload

required is validated, the “approved Navy Standard Afloat productive workweek is applied in a series of calculations to derive the staffing required” (McGovern, 2003, p. 3-2).

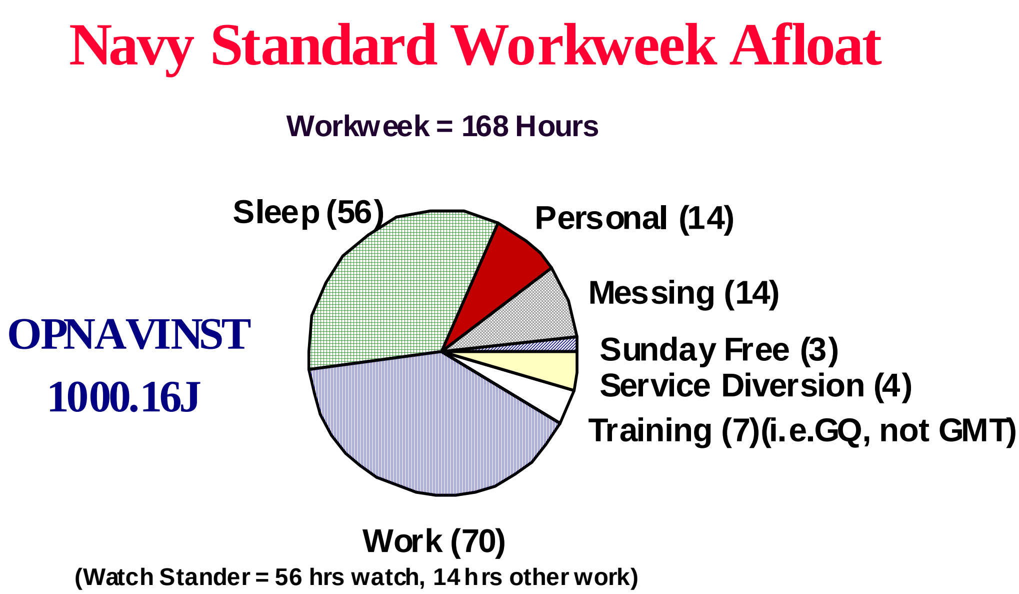

Figure 1. Navy Standard Workweek Afloat (From McGovern, 2003, p. 3–2)

E. STANDARDS AND METHODOLOGY OF THE MANPOWER REQUIREMENTS PROCESS

The Navy Manpower Requirements System (NMRS) is an automated information system that determines manpower requirements. The standards for determining manpower requirements are a collection of a measured workload and the essential skills necessary to perform identified tasks. Total workload is comprised of four standards used to calculate the operational manning.

1. Operational Manning

Operational Manning or "Watch Stations" is the quantitative and qualitative sum of manpower required to man operating stations during the different conditions of readiness. "Watch Stations" manpower requirements are specified by the ships' function. Qualitative requirements include requirements such as rate, rating, and Navy Enlisted Classification Code (NEC), that are determined by the Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068 (series). These are the minimum skills and training required to perform the duties of a particular watch station or function. Documentation to support a watch or station requirement is necessary to establish the need for manning for a particular operation. A comprehensive study and analysis is normally involved of each operating station in accordance to the requirements listed in the ROC.

2. Own Unit Support

Own Unit Support (OUS) is the quantitative sum of manpower necessary to perform administrative, command, supply, medical, and environmental management tasks, including shipboard evolutions. Because of the complexity and variety of skill levels associated with the various categories of OUS, there is no set work study technique used in developing OUS manpower requirements. Instead, data is gathered for the different functions using task analysis, operational audits and reviews, work measurement and method study, and work sampling.

3. Direct Requirements

Directed Requirements is the sum of the qualitative and quantitative manpower positions needed to perform duties directed by the CNO, CNO agents and/or special programs. Directed requirements are not necessarily driven by measured workloads. Instead they are often based on population size or unique skill. Workload and manhours are associated to a requirement or a unique skill. We found no further studies done justifying directed requirements that are written at the sole discretion of the Office of the

Chief of Naval Operations. An example of directed requirements may be for a platform to have a Command Master Chief, Navy Career Counselor, or Corpsman.

F. MAINTENANCE

Maintenance is the last variable in determining manpower requirements. Maintenance is the qualitative and quantitative sum of manpower that is required to perform planned, corrective and facilities maintenance. “Whether considering a routine maintenance action such as an oil change, equipment repair, or housekeeping work to maintain cleanliness, it meets the definitions for maintenance and the workload is quantifiable, it must be factored into maintenance manning” (McGovern, 2003, p. 3-6). Incremental times necessary to accomplish CM, PM, and FM are summed to provide a total maintenance manhour requirement. The source of maintenance manpower requirement can be traced back to the “other work” portion of the productive work week.

1. Planned Maintenance

Preventive maintenance is mandated by the Navy preventive maintenance system (PMS). “In quantitative terms, it is the total workload associated with the performance of preventive maintenance actions on operational systems, equipment, or components contributing to uninterrupted operations within design characteristics” (McGovern, 2003, p. 3-6). The only planned maintenance that is considered to be valid workload is maintenance conducted underway, during Condition III as specified in the ROC/POE. Only PM that is done quarterly or less is collected.

Total manhours associated with PM are: make-ready, accomplishing the maintenance action, put-away, and data recording. MRCs and MIPs record only average times required for actual tasks accomplished on the maintenance action. Make-ready, put-away, and documentation times are not excluded and therefore task times must be adjusted to account for these times in a PM action and to include the actual work allowances. “The accepted procedure for SMD development is to apply a 15 percent

factor for make-ready and put-away on PM only and a floating 2–8 percent productivity allowance factor for CM, FM and OUS workload" (McGovern, 2003, p. 3-8). Work elements associated with PM include:

- Make-Ready. This includes drawing the Maintenance Requirement Card (MRC); obtaining necessary instruction manuals, tools, and materials; transit to the work area; and any preparatory work that may be required, such as removal of interference, tagging-out of electrical circuits and valves.
- Accomplishment of the Maintenance Action. This includes completion of all procedures detailed listed on the MRC only.
- Put-Away. This includes necessary replacement of interference; cleanup; return of tools, manuals, and MRCs; removing all tag-outs and returning circuits and valves to their original positions, and any required transits.
- Data Recording. This includes completion of forms or other records reporting accomplishment of the maintenance action and is accounted for in the OUS workload category. (McGovern, 2003, p. 3-7)

2. Corrective Maintenance

Corrective Maintenance is unscheduled work that is done to repair malfunctions, failure, or deterioration of shipboard equipment. Quantitatively, it is "the workload associated with the restoration of disabled systems, equipment, or components to an operational condition within predetermined tolerances and limitations for which there is a corresponding PM action" (McGovern, 2003, p. 3-9). Make-ready, put-away, accomplishing of the corrective action, and data recording are also elements considered in determining total manhours.

Requirements for CM are determined by applying the PM:CM ratio. "If the PM:CM ratio was 1:1, then for each manhour allocated to PM, one additional manhour would be allocated to CM. If the PM:CM ratio was 2:1, then one-half hour of CM would be allocated for each hour of PM (Lurie, 1987, p. 1). Work elements associated with CM are defined below:

- Make-Ready. This includes obtaining necessary instruction manuals, tools, and materials; transit to the work area; tagging-out of electrical circuits and valves and removal of interference. Research necessary to determine part requirements and execution of supply of supply forms is also included in this element.
- Accomplishment of the Corrective (repair) Action. This includes opening of equipment, fault isolation, effecting necessary repairs, testing and adjustment, and closing equipment.
- Put-Away. This includes replacement of interference; necessary cleanup; return of tools and manuals; removing all tag-outs and returning circuits and valves to their original positions and any required transits.
- Data recording. This includes completion of necessary forms to report the action taken and preparation of a repair request, if the repair is beyond the capability of ship's force. Data recording is accounted for in the OUS workload category. (McGovern, 2003, p. 3–9)

3. Facility Maintenance

Facility Maintenance is the quantitative and qualitative sum of the manpower it takes to maintain the material condition of the ship. This includes cleanliness, sanitation of all living areas, preservation against corrosion and deterioration of hull, decks, superstructure, and equipment. Collecting data used to determine this workload consists of "digitizing space measurements and manually computing of FM workload" (McGovern, 2003, p. 3–9). Make-ready, put-away, and accomplishing of the corrective action are also elements considered in determining total manhours and are defined below:

- Make-ready. This includes obtaining necessary tools and materials, transits to the work area, and any advanced preparation such as rigging of boatswain's chairs, stages, floats, etc. (Not to be confused with MR/PA allowance for Preventive Maintenance).
- Accomplishment of the work action. This includes the actual accomplishment of a FM requirement. Examples of such requirements are:

  (a) sweeping and swabbing decks

  (b) cleaning of heads and compartments

  (c) painting (includes preparation of surfaces)

  (d) polishing bright work

- Put-Away. This includes necessary cleanup, breaking down of boatswain's chairs, stages, etc.; return or stowage of tools; and necessary transits. (Not to be confused with MR/PA allowance for Preventive Maintenance) (McGovern, 2003, p. 3–10)

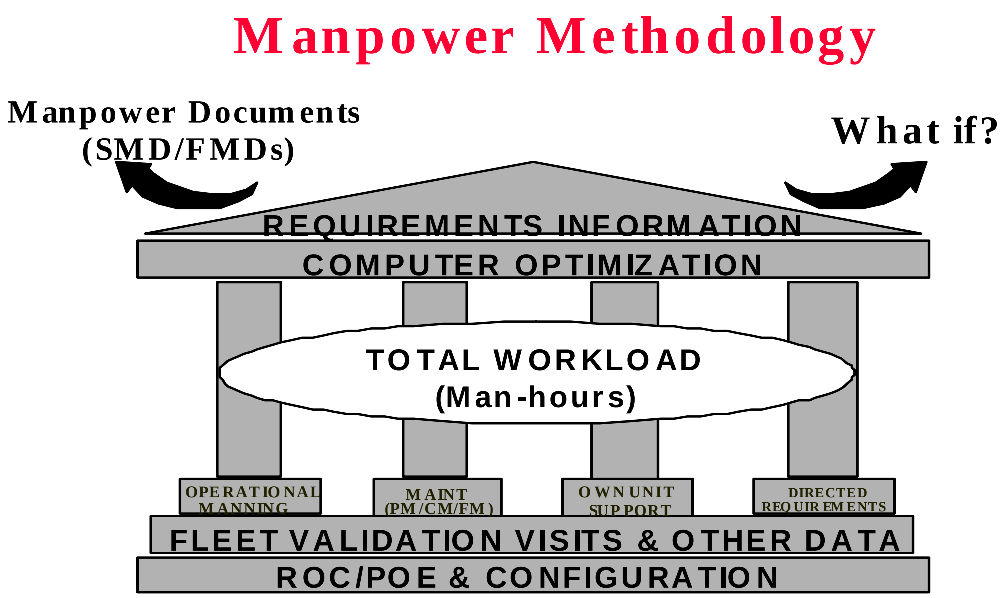

Figure 2. Manpower Methodology (From McGovern, 2003, p. 5–2)

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V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

This researched analyzed the current Corrective Maintenance for DDG class ships and compared it to the Preventive/Corrective maintenance (PM:CM) ratio used by the Navy Manpower Analysis Center (NAVMAC) as directed by OPNAVINST 1000.16K to establish Navy fleet manpower requirements. A site visit to a DDG in San Diego was conducted to observe how data was collected to validate the Ship Manpower Document (SMD) The current preventive maintenance ratio was established in 1968. Since then Make Ready/Put Away, productivity allowance, and watch standing hours have been modified, but the PM:CM ratio has remained unchanged. In 1987, the Center for Naval Analyses (CNA) was commissioned to study the PM:CM ratio. The study conducted by Lurie examined corrective maintenance performed on 14 electrical systems and 15 mechanical systems. The results produced 1:4 electrical and 1:3 mechanical ratios, supporting the likelihood that the Navy's ratio understated the corrective maintenance functional workload.

Based on the assessment of the data reviewed, corrective maintenance on board DDG-51 class ships is greater than what the PM:CM ratio predicts and what is reflected in the functional workload section of the Ship Manpower Document. Figures 3 and 4 show that in all instances, the PM:CM ratio derived using Open Architectural Retrieval System (OARS) data is higher than what the current ratio predicts. OARS data shows an average mechanical maintenance ratio of 1: 1.64 and an average electrical maintenance ratio of 1: 10.9. Appendices A through D show corrective maintenance hours by work center, ship hull, flight, total hours, weekly hours, and selected ship board systems.

The effect to SMD requirements is shown on Tables 4 and 5. Using OARS corrective maintenance data from this study, the requirements would increase on every flight for EA work center by an average of 3.2 requirements. The CF work center experienced an average increase of 2.7 requirements per flight in four of the five flights. The effect to SMD requirements if OPNAVINST 1000.16K and NAVMAC guidance

was strictly followed as shown in Table 6. The results show an average increase of 5.8 requirements in both the Engineering work center EA and Combat Systems work center CF affecting all flights.

B. CONCLUSION AND RECOMMENDATIONS

1. Primary Research Question

Does the current corrective maintenance in the SMD represent actual work as reported in NAVSEA OARS database?

a. Conclusion: The study concluded that corrective maintenance is not being identified correctly in manpower requirements. The data used for this analysis found the PM:CM ratios needs to change to 1:10.9 for electrical systems and 1:1.64 for mechanical. Our results show that the PM:CM ratio is approximately ten times higher for electrical systems and almost two times higher for mechanical systems than the current 1:1 and 2:1 ratio. Figures 1 and 2 show the PM:CM ratios based on our analysis. Factors that may contribute towards ratio(s) overestimation appear to stem from insufficient/inaccurate maintenance documentation and lack of awareness and training in this area.

In 2001, Required Operational Capabilities/Projected Operating Environment (ROC/POEs) were revised based on the optimum manning initiative, which changed the DDG-51 SMDs. The optimum manning initiative removed several billets from ships. Rather than eliminating or decreasing maintenance responsibilities, maintenance requirements were distributed to remaining onboard personnel (Balisle, 2010 p. 12).

> In 2002, the equation used to calculate minimum shipboard manpower requirements and reflected in a SMD changed. The Navy Standard Workweek Afloat increased from 67 to 70 productive hours per Sailor, which reduced shipboard manning by up to 4 percent. The revised equation also reduced the time allotted for Sailors to conduct preventive maintenance actions and reduced the productivity allowance applied for environmental fatigue and interruptions. (Balisle, 2010, p. 12)

This decrease in billets would appear to have generated at least two unintended consequences: increased the workload, thereby increasing the probability of insufficient/inaccurate maintenance documentation

The reduction in billets apparently reduces the time and personnel neeed to conduct on-the-job training. In 1999, external command inspections were eliminated and self assessment policies were implemented (Balisle, 2010, p. 13). Prior to this change, maintenance assist visits and inspections were available ships. "These inspections and assist visits brought system experts onboard and provided over-the-shoulder training to the crews. By 2001 there were only 35 of these inspections and assist visits available to the ships, drastically reducing the professional development and hands-on training of our Sailors" (Balisle, 2010, p. 13).

b. Recommendation: NAVSEA and NAVMAC co-author a study to determine actual shipboard maintenance based on OARS data and new ratios from this research.

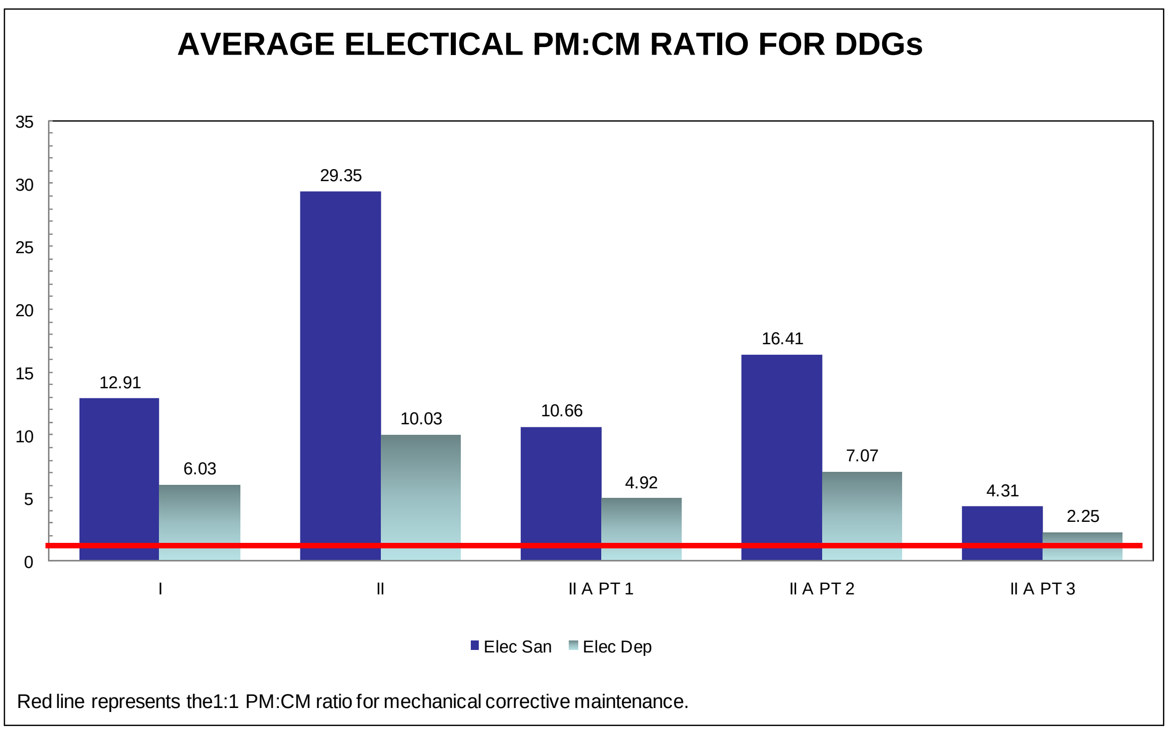


Figure 3. Electrical Systems PM:CM ratio based on our data

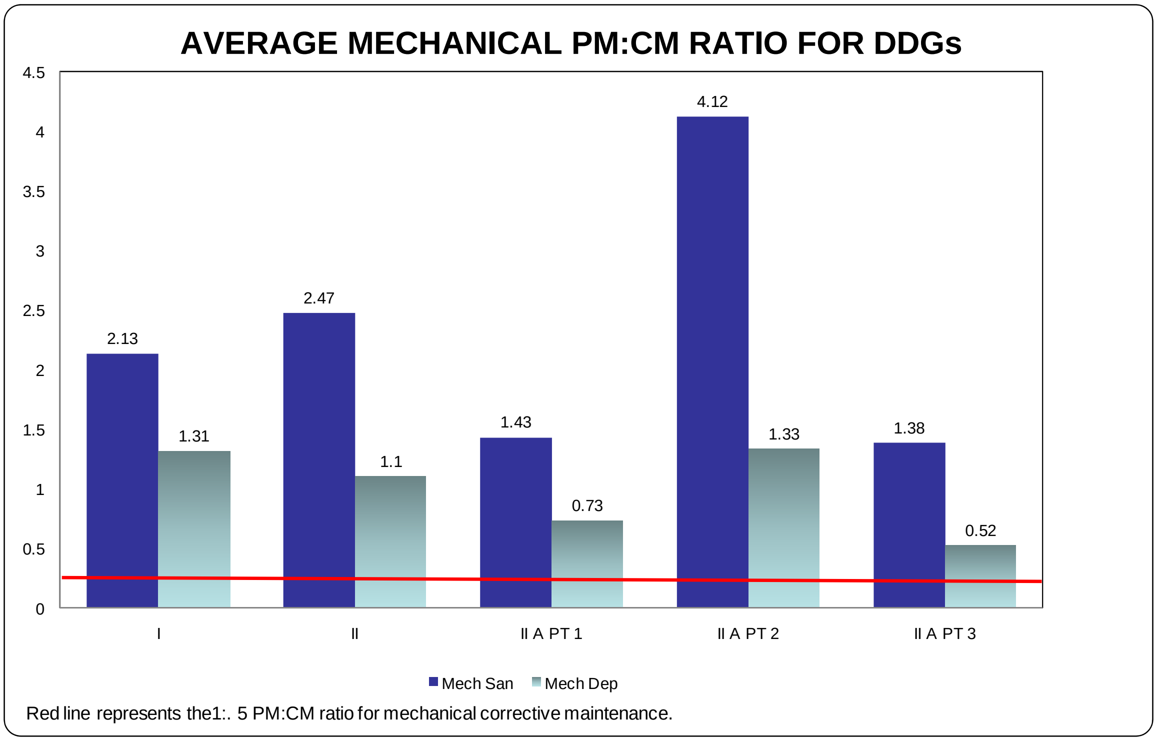


Figure 4. Mechanical Systems PM:CM ratio based on our data

2. Secondary Research Question

How does maintenance workload affect Manpower requirements?

a. Conclusion: The effect to SMD requirements for the EA work center when corrective maintenance hours from OARS are used in the place of the hours that are allotted in the original SMD are shown in Table 4. When corrective maintenance reported to OARS is used, the result increases requirements across all five flights of DDGs for the EA work center.

SMD INFORMATION					
Engineering Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
EA Division Authorized Billets	8	8	8	8	8
Operational Manning (watchstanding) hrs/week	224	224	224	224	224
Planned Maintenance hrs/week	110.7	33.7	33.7	38.6	85
Corrective Maintenance hrs/week	69.7	38.8	38.8	31.5	63.7
Own Unit Support hrs/week	107.6	101	101	101	100.9
Facilities Maintenance hrs/week	50.6	91.9	99.4	99.5	88.5
Productivity Allowance hrs/week	4.6	4.6	4.8	4.6	5.1
Service Diversion Allowance	32	32	32	32	32
Training	56	56	56	56	56
Total Division Hrs hrs/week	655.2	582.0	589.7	587.2	655.2
Hrs Per Billet	81.9	72.8	73.7	73.4	81.9
EA Division Authorized Billets	8	8	8	8	8

SMD INFORMATION					
Engineering Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
EA Division Authorized Billets	8	8	8	8	8
Operational Manning (watchstanding) hrs/week	224	224	224	224	224
Planned Maintenance hrs/week	110.7	33.7	33.7	38.6	85
Corrective Maintenance hrs/week	223.6	64.9	276.6	373.9	106.4
Own Unit Support hrs/week	107.6	101	101	101	100.9
Facilities Maintenance hrs/week	50.6	91.9	99.4	99.5	88.5
Productivity Allowance hrs/week	4.6	4.6	4.8	4.6	5.1
Service Diversion Allowance	32	32	32	32	32
Training	56	56	56	56	56
Total Division Hrs hrs/week	809.1	608.1	827.5	929.6	697.9
Hrs Per Billet	101.1	76.0	103.4	116.2	87.2
EA Division Authorized Billets	12	9	12	13	10

Table 4. Effects of SMD Requirements (EA Work Center)

The effect to SMD requirements for the CF work center when corrective maintenance hours from OARS are used in the place of the hours that are allotted in the original SMD as shown in Table 5. For the CF work center the use of OARS corrective maintenance data generated an increase in requirements in four of the five flights of DDGs. Flight IIA PT1 remained unchanged.

SMD INFORMATION					
Combat Systems Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
CF Division Authorized Billets	18	19	19	19	19
Operational Manning (watchstanding) hrs/week	840	840	840	840	840
Planned Maintenance hrs/week	19.1	44.7	44.8	51	53.3
Corrective Maintenance hrs/week	11.5	47.5	47.5	58.4	64.9
Own Unit Support hrs/week	120	108.1	108.1	108.1	108.1
Facilities Maintenance hrs/week	85.5	4.7	15.6	15.5	15.6
Productivity Allowance hrs/week	4.3	3.2	3.4	3.6	3.8
Service Diversion Allowance	76	76	76	76	76
Training	133	133	133	133	133
Total Division Hrs hrs/week	1289.4	1257.2	1268.4	1285.6	1294.7
Hrs Per Billet	71.6	66.2	66.8	67.7	68.1
CF Division Authorized Billets	18	19	19	19	19

SMD INFORMATION					
Combat Systems Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
CF Division Authorized Billets	18	19	19	19	19
Operational Manning (watchstanding) hrs/week	840	840	840	840	840
Planned Maintenance hrs/week	19.1	44.7	44.8	51	53.3
Corrective Maintenance hrs/week	189.9	230.9	121.4	445.3	144.4
Own Unit Support hrs/week	120	108.1	108.1	108.1	108.1
Facilities Maintenance hrs/week	85.5	4.7	15.6	15.5	15.6
Productivity Allowance hrs/week	4.3	3.2	3.4	3.6	3.8
Service Diversion Allowance	76	76	76	76	76
Training	133	133	133	133	133
Total Division Hrs hrs/week	1467.8	1440.56	1342.29	1672.47	1374.19
Hrs Per Billet	81.5	75.8	70.6	88.0	72.3
CF Division Authorized Billets	21	21	19	24	20

Table 5. Effects of SMD Requirements (CF Work Center)

Table 6 examines how SMD requirements would differ in the EA work center if the SMD generated requirements based on the guidance in OPNAVINST 1000.16K. The effect to requirements in the EA work center is an increase of 4–8 (50–100 percent) requirements across the five flights. Flight IIA PT2 saw had a 100 percent increase in requirements.

SMD INFORMATION					
Engineering Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
EA Division Authorized Billets	8	8	8	8	8
Operational Manning (watchstanding) hrs/week	224	224	224	224	224
Planned Maintenance hrs/week	110.7	33.7	33.7	38.6	85
Corrective Maintenance hrs/week	69.7	38.8	38.8	31.5	63.7
Own Unit Support hrs/week	107.6	101	101	101	100.9
Facilities Maintenance hrs/week	50.6	91.9	99.4	99.5	88.5
Productivity Allowance hrs/week	4.6	4.6	4.8	4.6	5.1
Service Diversion Allowance	32	32	32	32	32
Training	56	56	56	56	56
Total Division Hrs hrs/week	655.2	582.0	589.7	587.2	655.2
Hrs Per Billet	81.9	72.8	73.7	73.4	81.9
EA Division Authorized Billets	8	8	8	8	8

Based on OARS data and Navy Standard Workweek Allowances					
Engineering Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
EA Division Authorized Billets	8	8	8	8	8
Operational Manning (watchstanding)[1] hrs/week	**448**	**448**	**448**	**448**	**448**
Planned Maintenance[2] hrs/week	**14.7**	**13.6**	**19.8**	**19.8**	**19.8**
Corrective Maintenance[3] hrs/week	**223.6**	**64.9**	**276.6**	**373.9**	**106.4**
Own Unit Support hrs/week	107.6	101.0	101.0	101.0	100.9
Facilities Maintenance hrs/week	50.6	91.9	99.4	99.5	88.5
Productivity Allowance[4] hrs/week	**7.6**	**5.2**	**9.5**	**11.5**	**5.9**
Service Diversion Allowance[1]	**32**	**32**	**32**	**32**	**32**
Training[1]	**56**	**56**	**56**	**56**	**56**
Total Division Hrs[5] hrs/week	**940.1**	**812.6**	**1042.3**	**1141.7**	**857.5**
Hrs Per Billet[1]	**117.5**	**101.6**	**130.3**	**142.7**	**107.2**
EA Division Authorized Billets	**13**	**12**	**15**	**16**	**12**

NOTES

1. Based on Navy Standard Workweek and requirements in SMD(OPNAVINST 1000.16K, C-3)
2. Provide d by NAVMAC (Self-reported by ship as PM peformed)-Does not include 15% Make Ready/Put Away (MR/PA) allowance
3. Based on corrective maintenance in the OARS database by ship- Does not include 40% Ship class age factor used for ships averaging less than 20 years old.
4. As defined in brief provided by NAVMAC. 2% for EA work center and 6% for CF work center
5. The sum of Operational manning, planned maintenance, corrective maintenance, own unit support, facilities maintenance, and productivity allowance.
6. Based on Navy Standard Workweek (OPNAVINST 1000.16K, C-8)

Table 6. SMD Comparison (EA Work Center)

Table 7 examines how SMD requirements would differ in the CF work center if the SMD generated requirements based on the guidance in OPNAVINST 1000.16K. The effect to requirements in the EA work center is an increase of 5–9 (33–47 percent) requirements across the five flights. Flight IIA PT2 had a 47 percent increase in requirements.

SMD INFORMATION					
Combat Systems Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
CF Division Authorized Billets	18	19	19	19	19
Operational Manning (watchstanding) hrs/week	840	840	840	840	840
Planned Maintenance hrs/week	19.1	44.7	44.8	51	53.3
Corrective Maintenance hrs/week	11.5	47.5	47.5	58.4	64.9
Own Unit Support hrs/week	120	108.1	108.1	108.1	108.1
Facilities Maintenance hrs/week	85.5	4.7	15.6	15.5	15.6
Productivity Allowance hrs/week	4.3	3.2	3.4	3.6	3.8
Service Diversion Allowance	76	76	76	76	76
Training	133	133	133	133	133
Total Division Hrs hrs/week	1289.4	1257.2	1268.4	1285.6	1294.7
Hrs Per Billet	71.6	66.2	66.8	67.7	68.1
CF Division Authorized Billets	18	19	19	19	19

Based on OARS data and Navy Standard Workweek Allowances					
Combat Systems Dept	Flight I	Flight II	Flight IIA PT 1	Flight IIA PT2	Flight II A PT 3
EA Division Authorized Billets	18	19	19	19	19
Operational Manning (watchstanding)[1] hrs/week	1008	1064	1064	1064	1064
Planned Maintenance[2] hrs/week	70.4	75.3	84.8	85.2	94.4
Corrective Maintenance[3] hrs/week	189.9	230.9	121.4	445.3	144.4
Own Unit Support hrs/week	120.0	108.1	108.1	108.1	108.1
Facilities Maintenance hrs/week	85.5	4.7	15.6	15.5	15.6
Productivity Allowance[4] hrs/week	23.7	20.6	14.7	34.1	16.1
Service Diversion Allowance[1]	76	76	76	76	76
Training[1]	133	133	133	133	133
Total Division Hrs[5] hrs/week	1706.6	1712.6	1617.5	1961.2	1651.5
Hrs Per Billet[1]	94.8	90.1	85.1	103.2	86.9
CF Division Authorized Billets	24	24	23	28	24

NOTES
1. Based on Navy Standard Workweek and requirements in SMD(OPNAVINST 1000.16K, C-3)
2. Provide d by NAVMAC (Self-reported by ship as PM peformed)-Does not include 15% Make Ready/Put Away (MR/PA) allowance
3. Based on corrective maintenance in the OARS database by ship- Does not include 40% Ship class age factor used for ships averaging less than 20 years old.
4. As defined in brief provided by NAVMAC. 2% for EA work center and 6% for CF work center
5. The sum of Operational manning, planned maintenance, corrective maintenance, own unit support, facilities maintenance, and productivity allowance.
6. Based on Navy Standard Workweek (OPNAVINST 1000.16K, C-8)

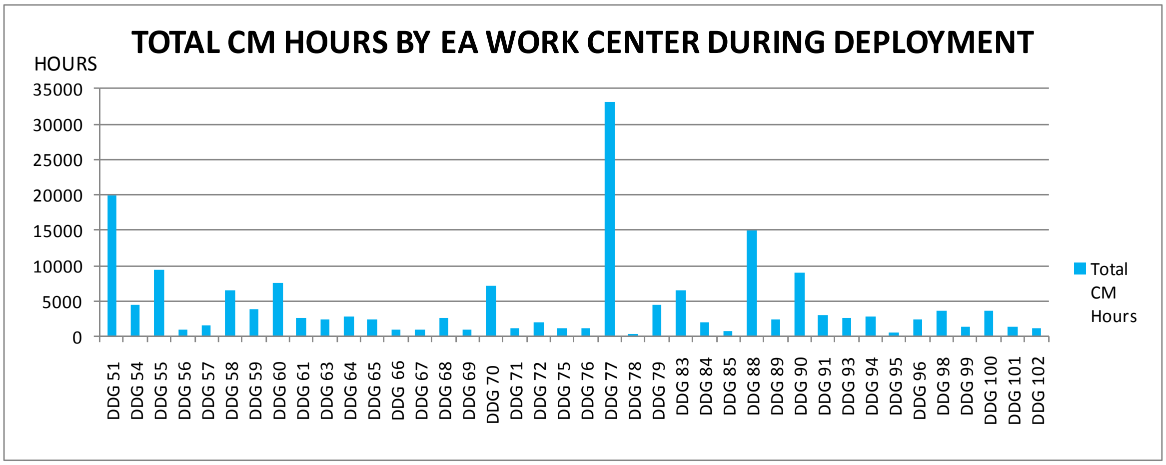
Table 7. SMD Comparison (CF Work Center)

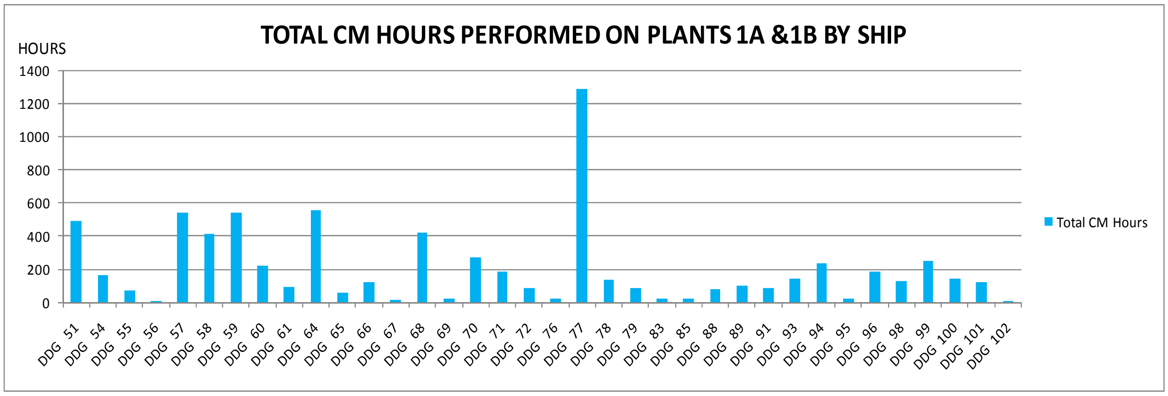
In both the EA and CF work centers, requirements increased when the OARS CM data was used to generate requirements. The OPNAVINST 1000.16K states that NAVMAC may use validated corrective maintenance workload to create the SMDs. In both of our examples, if workload would have been used, it would have resulted in increased requirements to the EA and CF work centers.

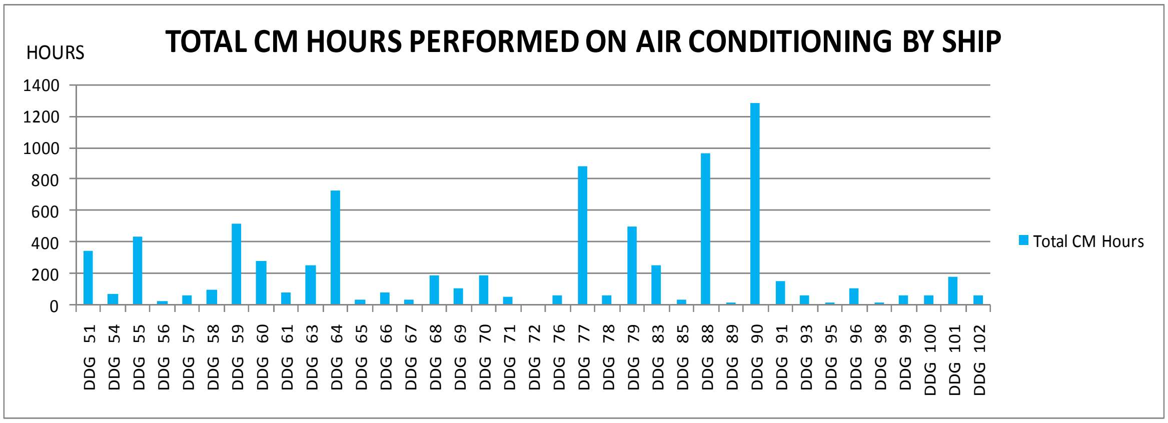
b. Recommendations:

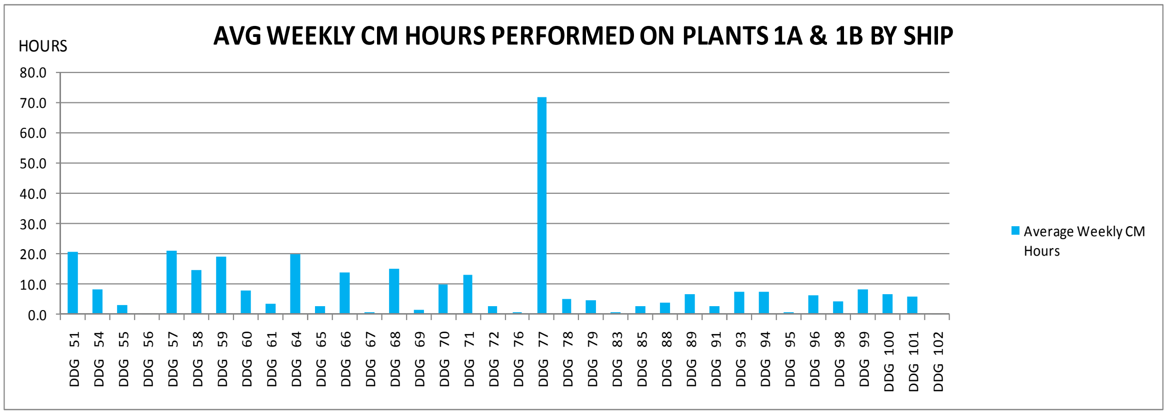
- We recommend that further comparisons be completed across all divisions on other ships in this class to validate the results of this study.
- Commanding Officers and Maintenance and Material Management System Coordinators (3MC) need to validate OARS data once compiled in final form to NAVMAC.

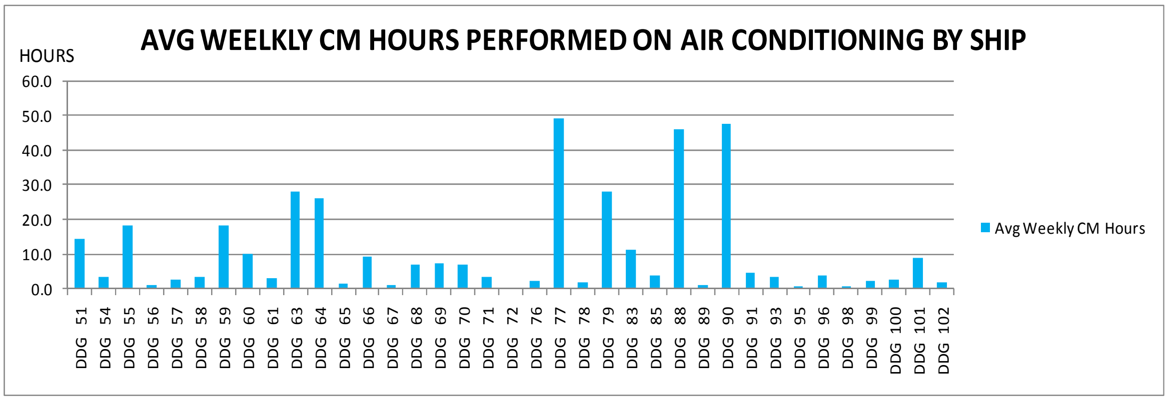
APPENDIX A. EA WORK CENTER CORRECTIVE MAINTENANCE TOTAL HOURS BY SHIP



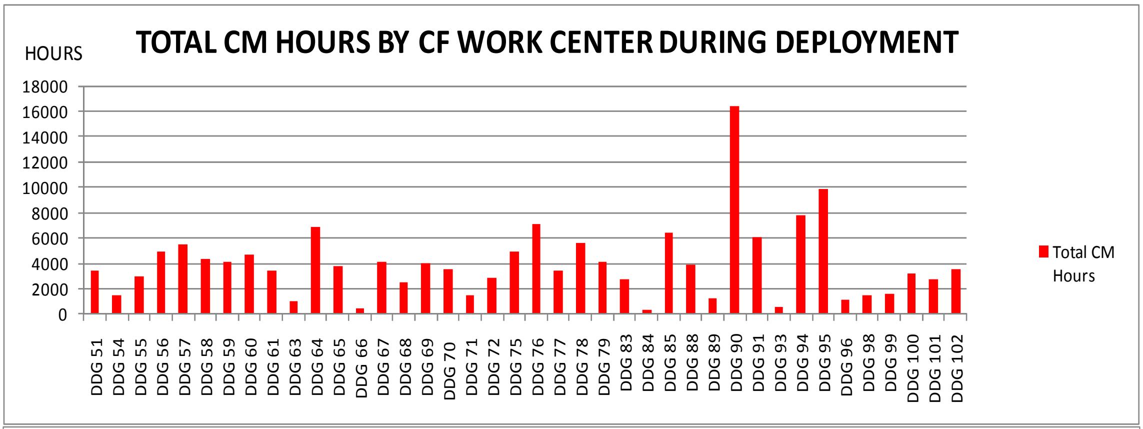


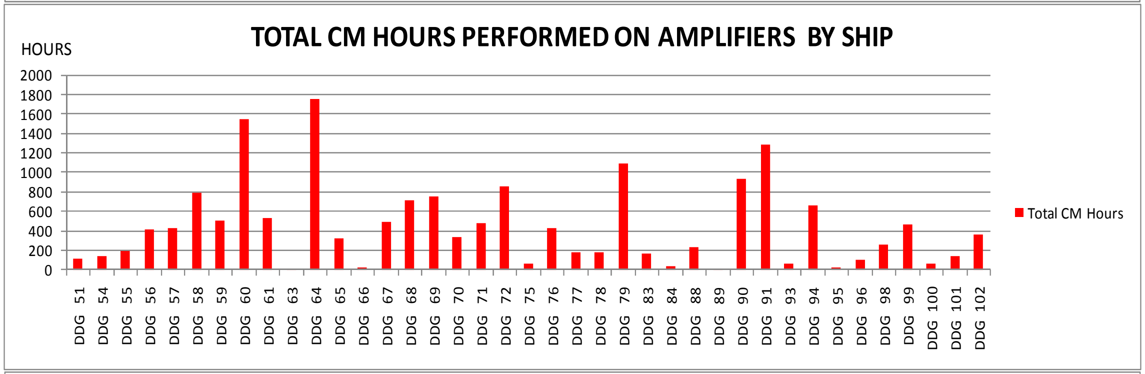


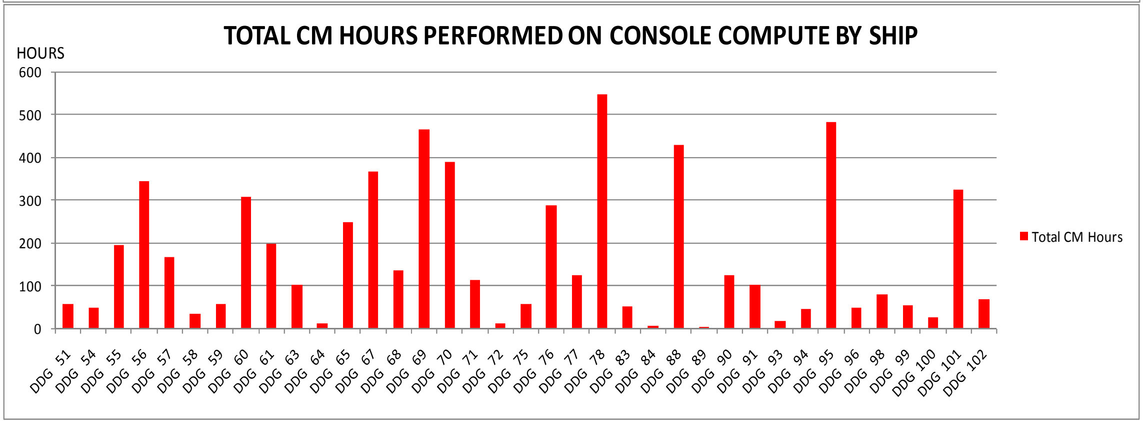

AVG WEEKLY CM HOURS PERFORMED ON PLANTS 1A & 1B BY SHIP
HOURS
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
DDG 51
DDG 54
DDG 55
DDG 56
DDG 57
DDG 58
DDG 59
DDG 60
DDG 61
DDG 64
DDG 65
DDG 66
DDG 67
DDG 68
DDG 69
DDG 70
DDG 71
DDG 72
DDG 76
DDG 77
DDG 78
DDG 79
DDG 83
DDG 85
DDG 88
DDG 89
DDG 91
DDG 93
DDG 94
DDG 95
DDG 96
DDG 98
DDG 99
DDG 100
DDG 101
DDG 102
Average Weekly CM Hours

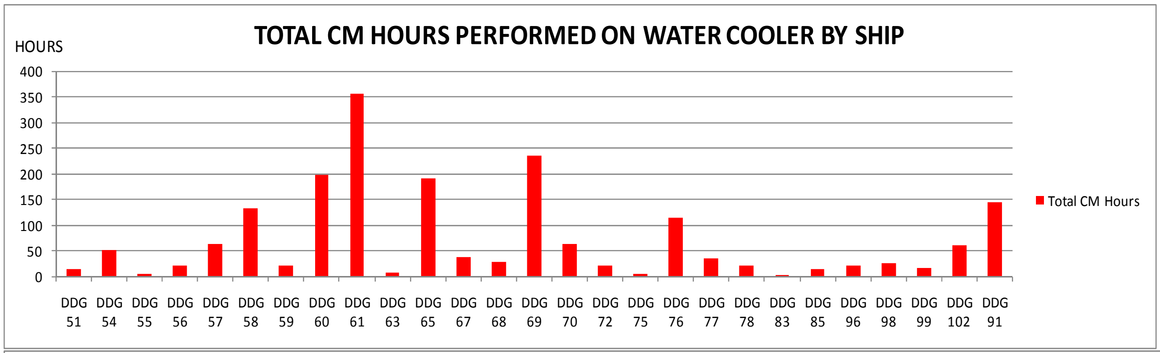

AVG WEELKLY CM HOURS PERFORMED ON AIR CONDITIONING BY SHIP
HOURS
60.0
50.0
40.0
30.0
20.0
10.0
0.0
DDG 51
DDG 54
DDG 55
DDG 56
DDG 57
DDG 58
DDG 59
DDG 60
DDG 61
DDG 63
DDG 64
DDG 65
DDG 66
DDG 67
DDG 68
DDG 69
DDG 70
DDG 71
DDG 72
DDG 76
DDG 77
DDG 78
DDG 79
DDG 83
DDG 85
DDG 88
DDG 89
DDG 90
DDG 91
DDG 93
DDG 95
DDG 96
DDG 98
DDG 99
DDG 100
DDG 101
DDG 102
Avg Weekly CM Hours

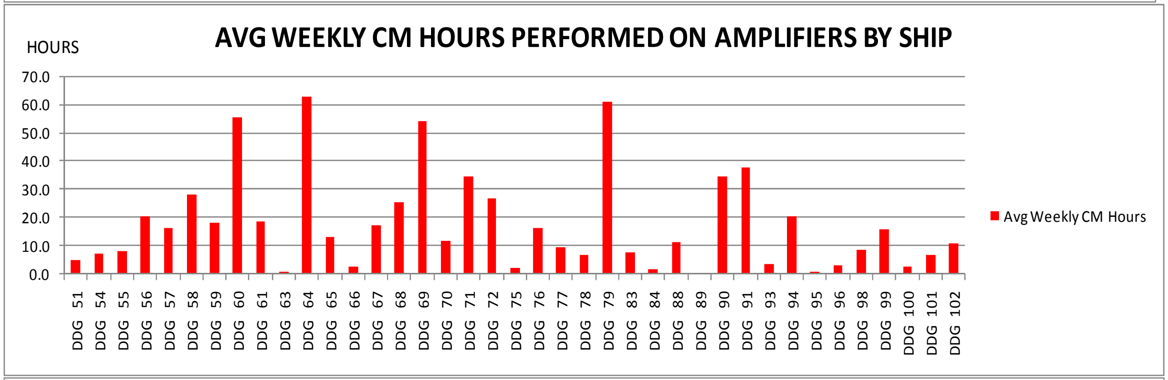
APPENDIX B. CF WORK CENTER CORRECTIVE MAINTENANCE TOTAL HOURS BY SHIP

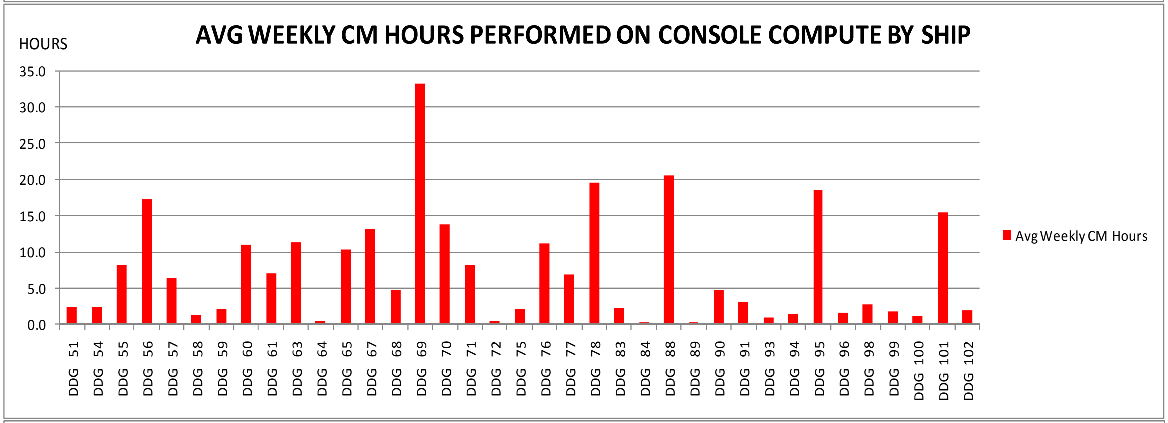


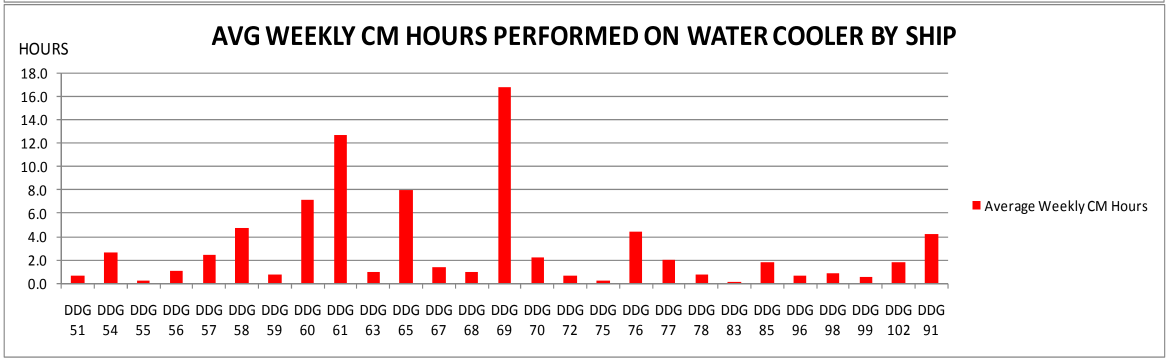




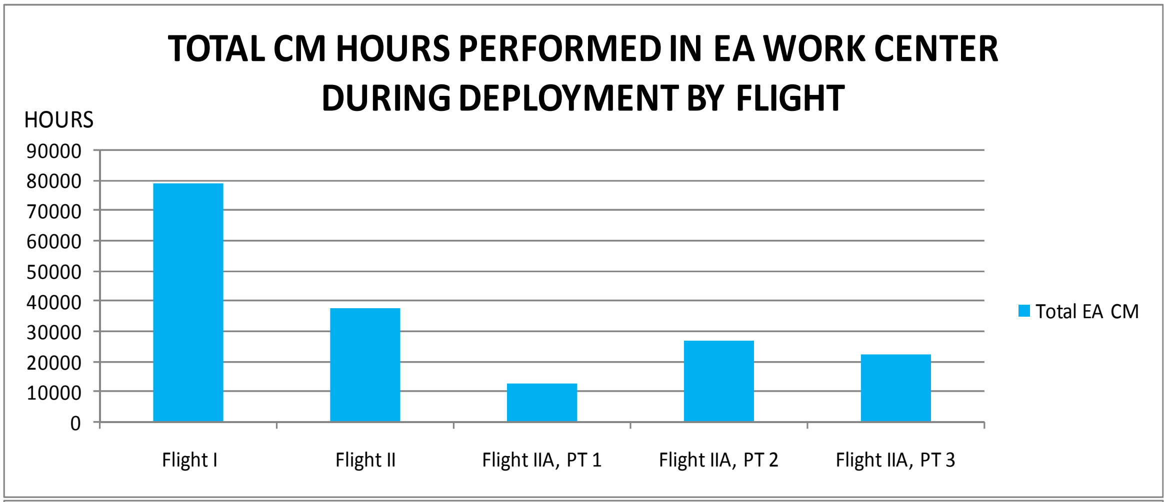

TOTAL CM HOURS PERFORMED ON WATER COOLER BY SHIP
HOURS
Total CM Hours
DDG 51
DDG 54
DDG 55
DDG 56
DDG 57
DDG 58
DDG 59
DDG 60
DDG 61
DDG 63
DDG 65
DDG 67
DDG 68
DDG 69
DDG 70
DDG 72
DDG 75
DDG 76
DDG 77
DDG 78
DDG 83
DDG 85
DDG 96
DDG 98
DDG 99
DDG 102
DDG 91

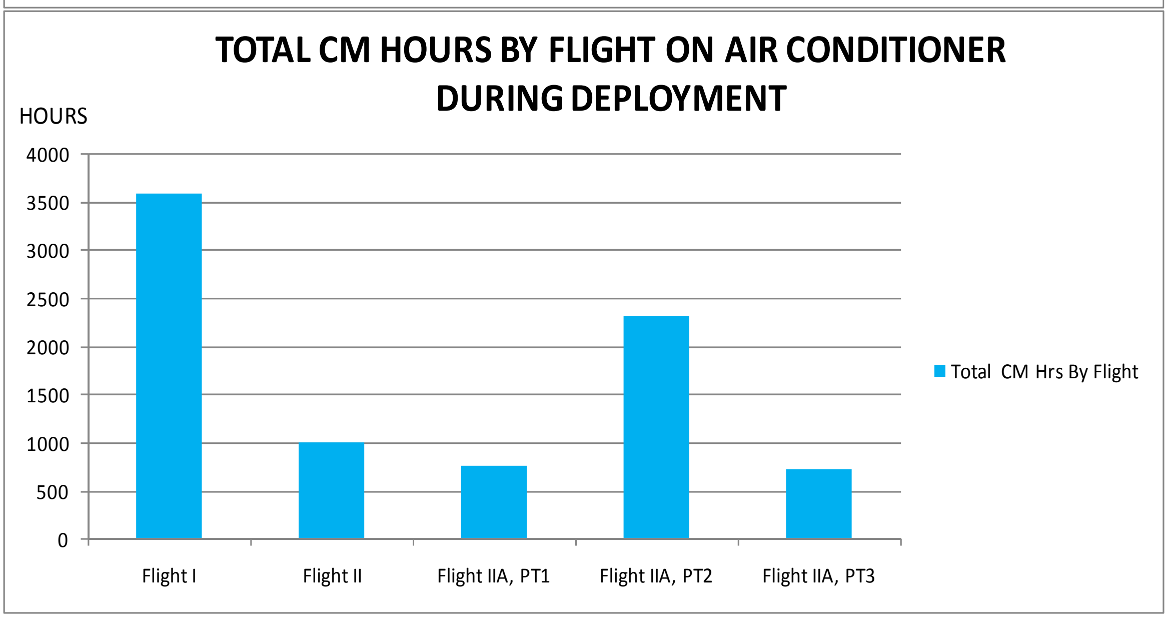

AVG WEEKLY CM HOURS PERFORMED ON AMPLIFIERS BY SHIP
HOURS
Avg Weekly CM Hours

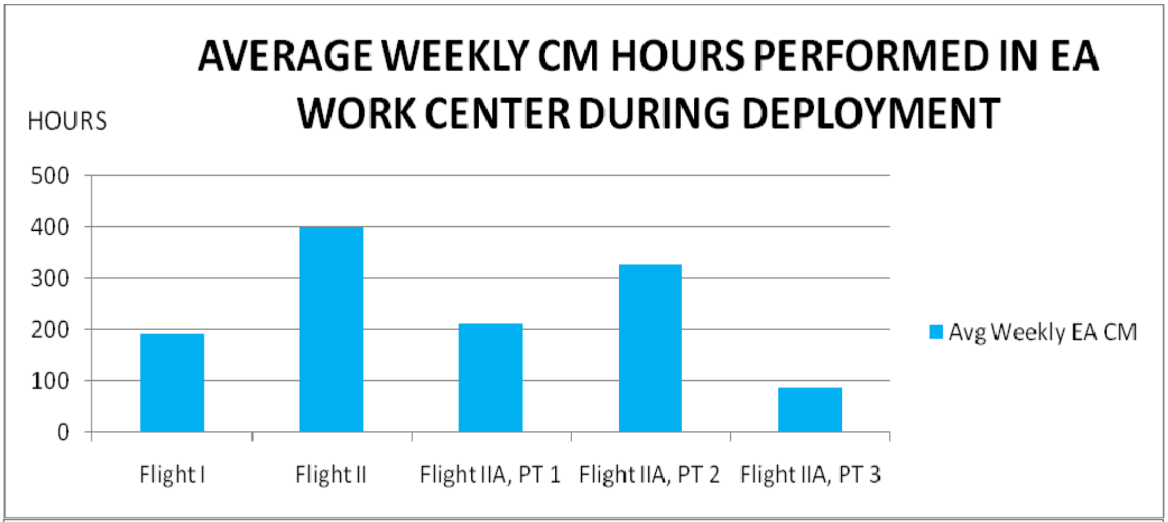

AVG WEEKLY CM HOURS PERFORMED ON CONSOLE COMPUTE BY SHIP
HOURS
Avg Weekly CM Hours

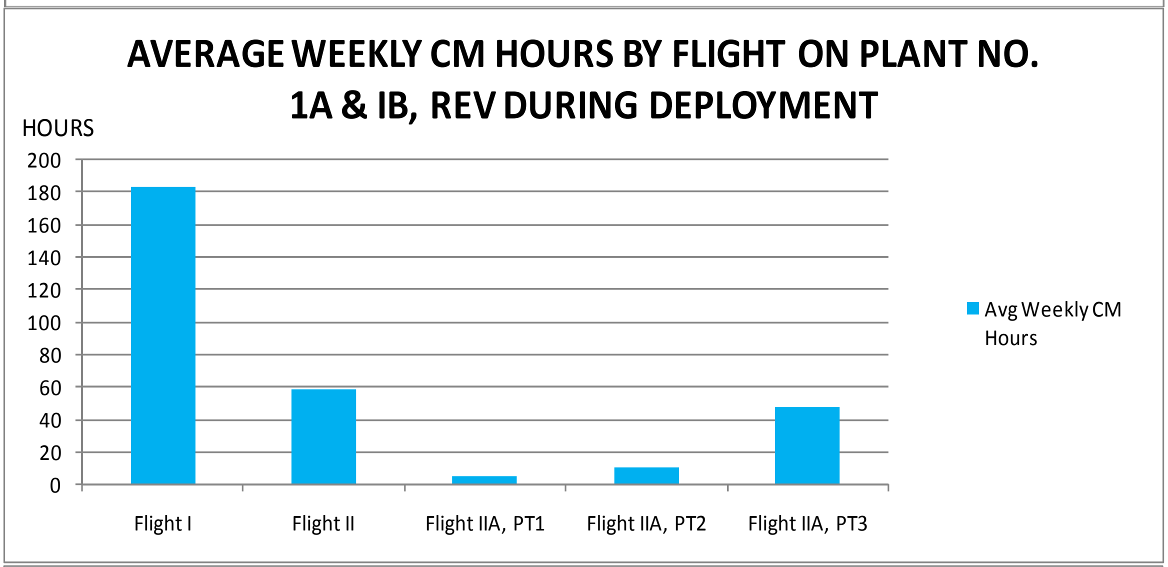

AVG WEEKLY CM HOURS PERFORMED ON WATER COOLER BY SHIP
HOURS
Average Weekly CM Hours

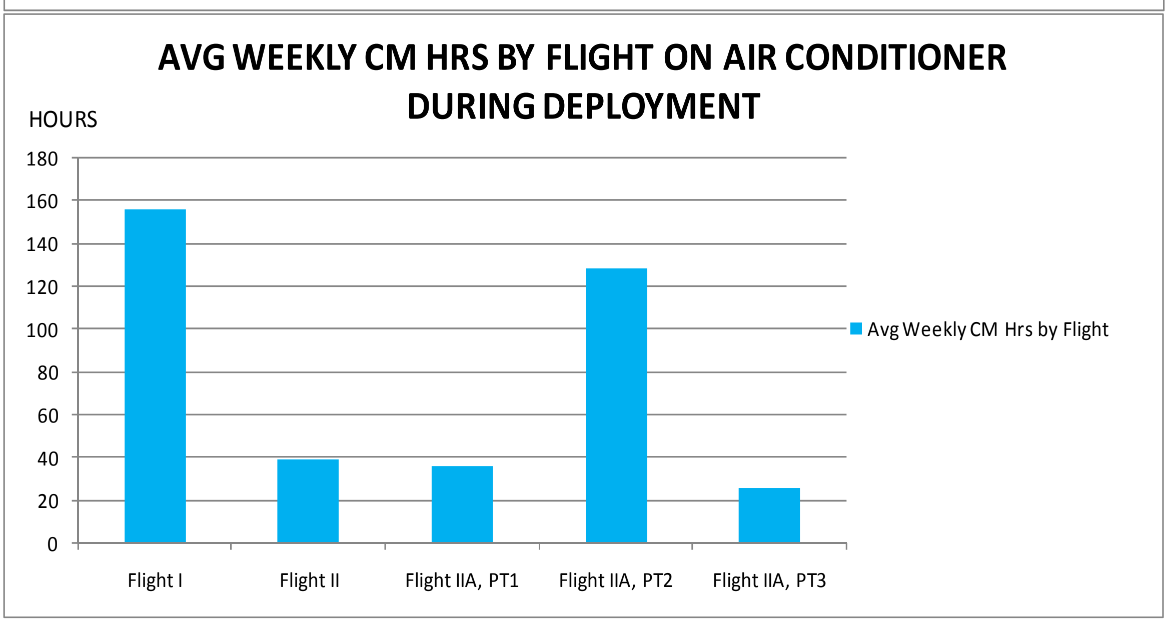
APPENDIX C. EA WORK CENTER CORRECTIVE MAINTENANCE AVERAGE HOURS BY FLIGHT



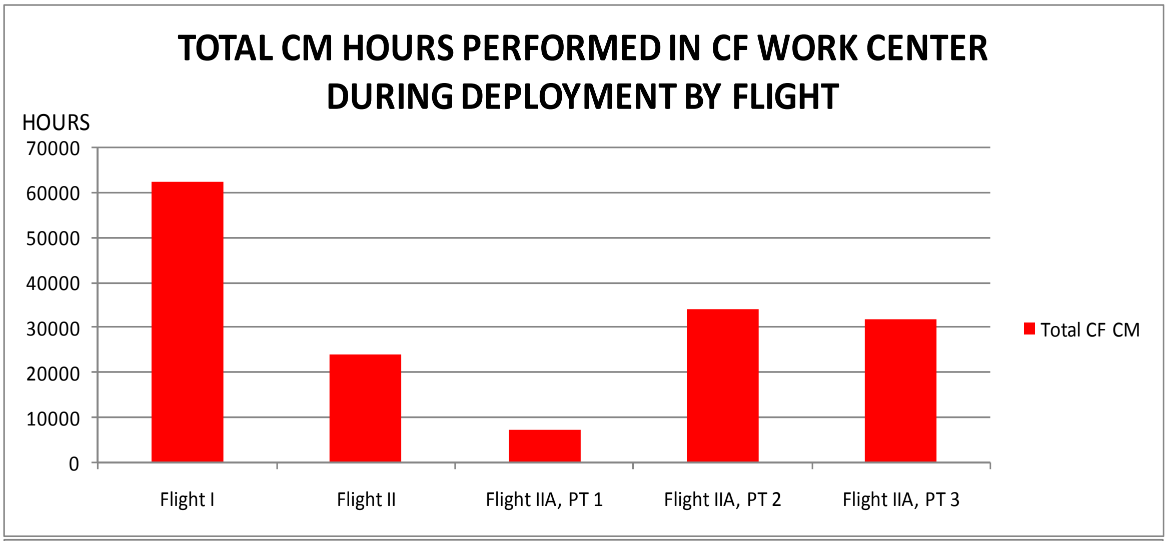


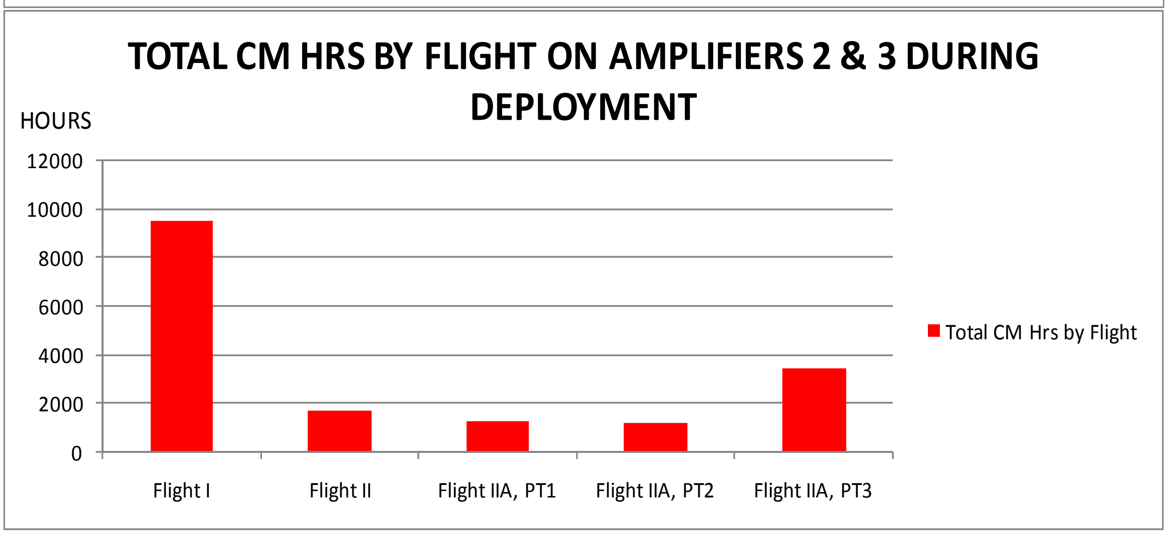

AVERAGE WEEKLY CM HOURS PERFORMED IN EA WORK CENTER DURING DEPLOYMENT
HOURS
500
400
300
200
100
0
Flight I
Flight II
Flight IIA, PT 1
Flight IIA, PT 2
Flight IIA, PT 3
Avg Weekly EA CM

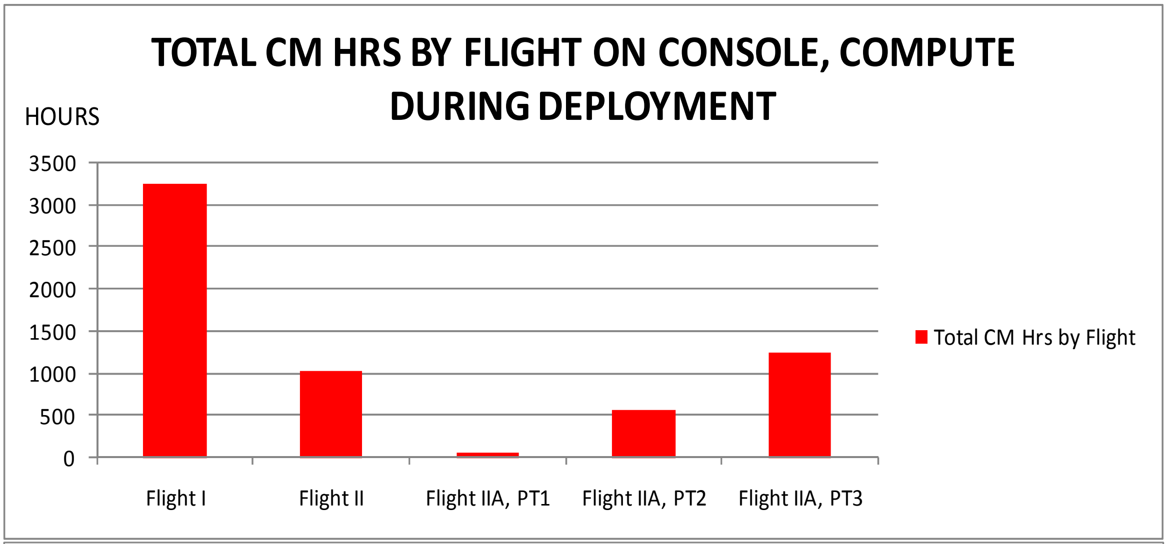

AVERAGE WEEKLY CM HOURS BY FLIGHT ON PLANT NO. 1A & IB, REV DURING DEPLOYMENT
HOURS
200
180
160
140
120
100
80
60
40
20
0
Flight I
Flight II
Flight IIA, PT1
Flight IIA, PT2
Flight IIA, PT3
Avg Weekly CM Hours

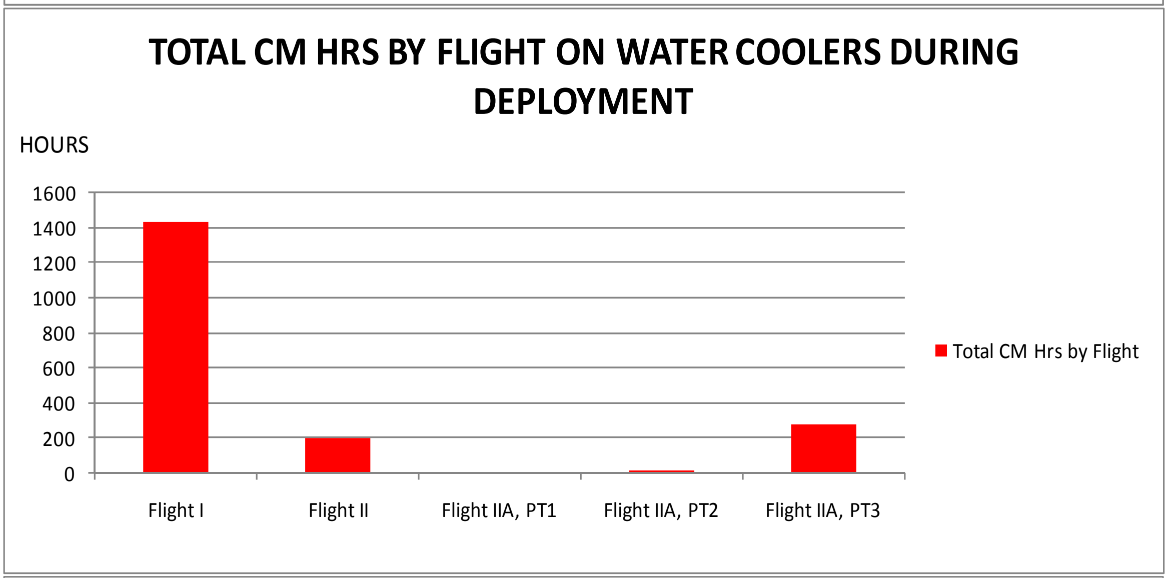

AVG WEEKLY CM HRS BY FLIGHT ON AIR CONDITIONER DURING DEPLOYMENT
HOURS
180
160
140
120
100
80
60
40
20
0
Flight I
Flight II
Flight IIA, PT1
Flight IIA, PT2
Flight IIA, PT3
Avg Weekly CM Hrs by Flight

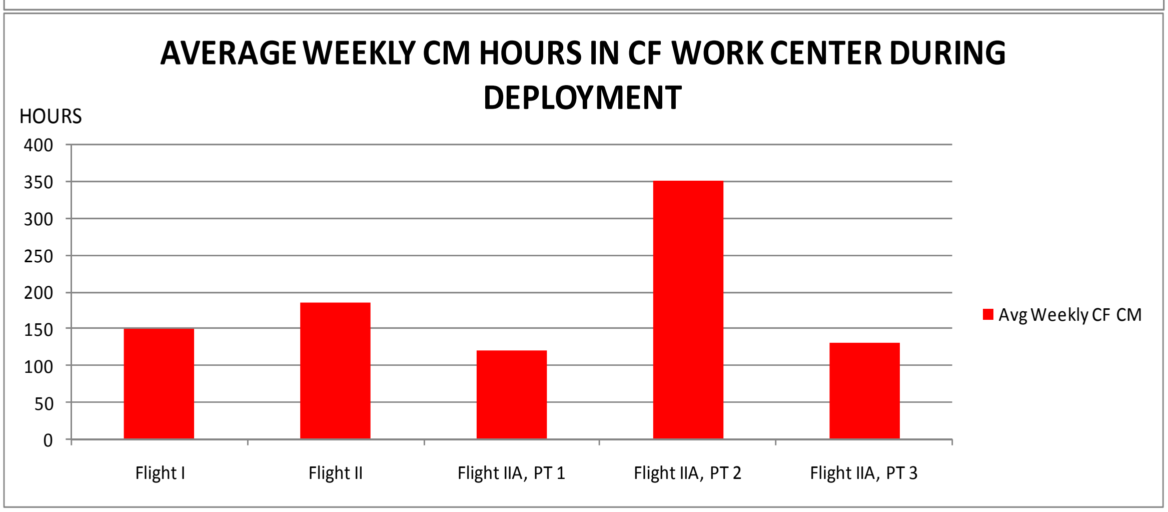
APPENDIX D. CF WORK CENTER CORRECTIVE MAINTENANCE AVERAGE HOURS BY FLIGHT

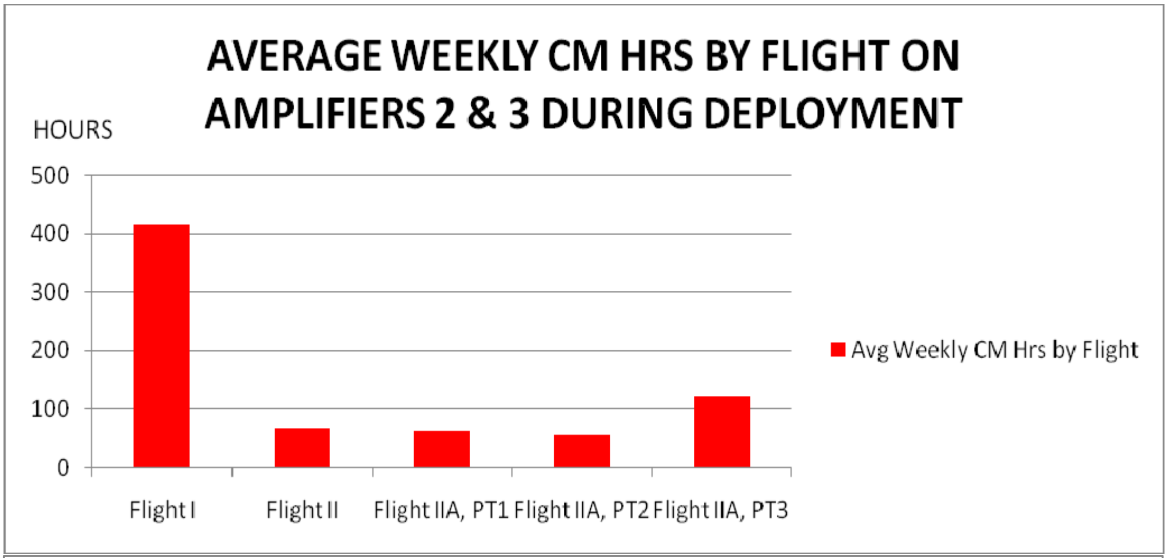


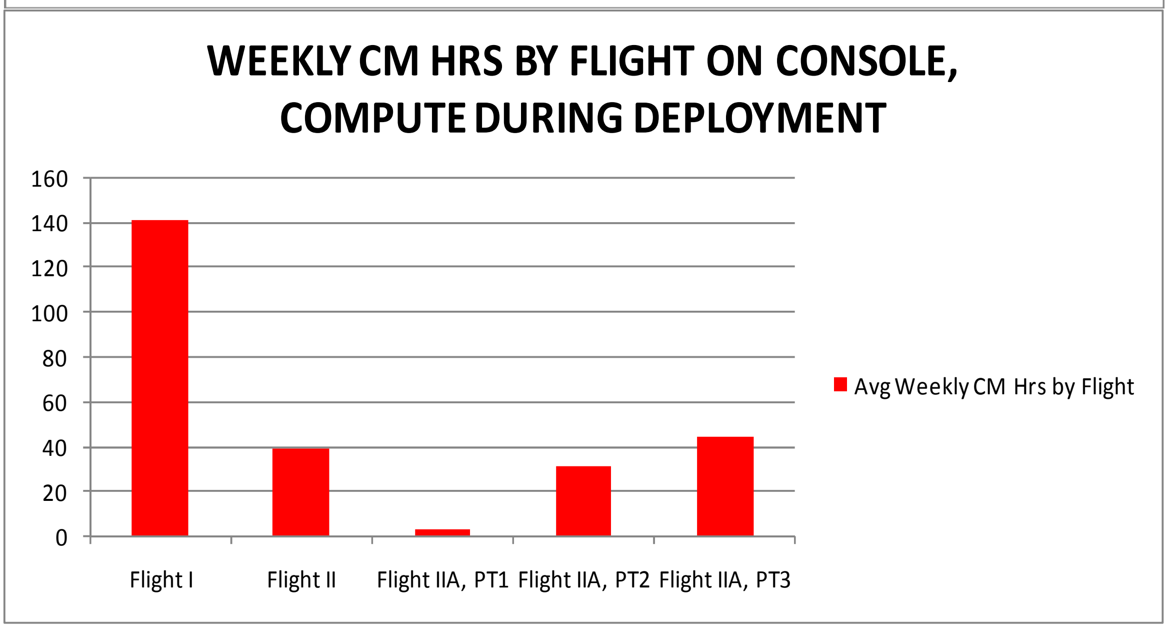


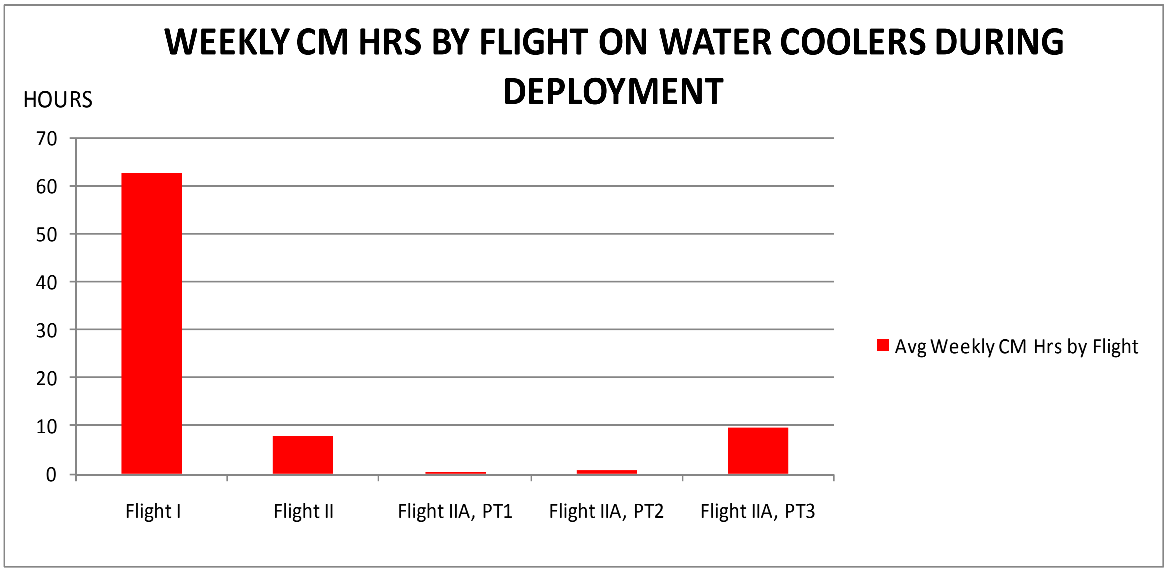

TOTAL CM HRS BY FLIGHT ON CONSOLE, COMPUTE DURING DEPLOYMENT
HOURS
3500
3000
2500
2000
1500
1000
500
0
Flight I
Flight II
Flight IIA, PT1
Flight IIA, PT2
Flight IIA, PT3
Total CM Hrs by Flight


TOTAL CM HRS BY FLIGHT ON WATER COOLERS DURING DEPLOYMENT
HOURS
1600
1400
1200
1000
800
600
400
200
0
Flight I
Flight II
Flight IIA, PT1
Flight IIA, PT2
Flight IIA, PT3
Total CM Hrs by Flight


AVERAGE WEEKLY CM HOURS IN CF WORK CENTER DURING DEPLOYMENT
HOURS
400
350
300
250
200
150
100
50
0
Flight I
Flight II
Flight IIA, PT 1
Flight IIA, PT 2
Flight IIA, PT 3
Avg Weekly CF CM


AVERAGE WEEKLY CM HRS BY FLIGHT ON AMPLIFIERS 2 & 3 DURING DEPLOYMENT
HOURS
500
400
300
200
100
0
Flight I
Flight II
Flight IIA, PT1
Flight IIA, PT2
Flight IIA, PT3
Avg Weekly CM Hrs by Flight


WEEKLY CM HRS BY FLIGHT ON CONSOLE, COMPUTE DURING DEPLOYMENT
160
140
120
100
80
60
40
20
0
Flight I
Flight II
Flight IIA, PT1
Flight IIA, PT2
Flight IIA, PT3
Avg Weekly CM Hrs by Flight


WEEKLY CM HRS BY FLIGHT ON WATER COOLERS DURING DEPLOYMENT
HOURS
70
60
50
40
30
20
10
0
Flight I
Flight II
Flight IIA, PT1
Flight IIA, PT2
Flight IIA, PT3
Avg Weekly CM Hrs by Flight

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